

VOLUME 4, NO. 1, JANUARY, 2013

# Pr<sup>☀</sup>opagation

A Journal of Science Communication



**National Council of Science Museums**

33, Block GN, Sector V, Bidhan Nagar, Kolkata - 700 091, India

January 2013

Volume 4

Number 1

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## Editorial

For our readers, I would like to begin on an apologetic note for the inordinate delay in bringing out this issue.

This particular issue is somewhat special in the sense that all the contributions are from professional science communicators who share their experiences and knowledge on specific areas of their works.

The article 'Science Popularization in India : Historical Initiatives' presents a historical narrative of science popularization activities in this country and emphasizes that an understanding of how motivations and contexts of science popularization change over time can actually help tackle the challenges faced by science communicators today.

'Remembering Ved Prakash Beri' provides a biographical account of one of the pioneers of India's science museum movement and science popularization activities.

India is now on the verge of achieving an unprecedented milestone of being declared a polio free nation. The article 'Global Effort for Polio Eradication: India on the Verge of Being Declared Polio Free' focuses on the history of the development of polio vaccine and chronicles the global efforts for its eradication with special emphasis on India.

Building a popular science exhibition on a socio-cultural theme as enigmatic as the River Ganga is by all means a challenging task. In the article 'The Ganga Gallery: Science Exhibition on a Socio-Cultural Theme', the author provides an interesting narrative of how the topic was dealt with in the exhibition.

The article 'Portrayal of the Present State of Biomedical Science and Technology at Regional Science Centre, Jaipur' deals with the narrative of a science centre gallery that highlights the progress of medicine from prehistoric times to the present day not as a continuum of inventions and discoveries but as discrete steps of shifting paradigms in diverse fields of knowledge.

'Deciphering Human Microbiome', the last article, reviews the human micro-biome project which was launched to decipher the identity and interactions of the microbes that inhabit our body, and provides the readers a general idea about human micro-biome and the novel techniques used to identify these microbes and their interactions with the human body.

We hope our readers will find the articles in this issue interesting and useful, and will look forward to their feedback and constructive suggestions.

E Islam  
*Chief Editor*

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## Science Popularization in India : Historical Initiatives

**Subodh Mahanti**

Science popularization, the attempt to take science to the public, began with the very process of creating modern science in Europe. The same might have happened in ancient and middle ages. At the beginning the creators of science themselves acted as popularizers of science. Galileo is regarded as father of modern science. His 'Dialogue on the Two Chief World Systems, Ptolemaic and Copernican' published in 1632 marked a crucial moment in the scientific revolution. Galileo made serious attempts to inform the public about the new discoveries in physics and astronomy through his public lectures and writings<sup>1,2</sup>.

In India like many other parts of the world science popularization began in the nineteenth century before modern science took roots in the country. Early attempts of science popularization or preparing the ground for it were made by social reformers, educationists, science teachers in schools and colleges and government officials managing the scientific departments. Srirampur (also Serampore) College, established in 1818 by three missionaries namely William Carey, Joshua Marshman and William Ward was the first Indian college for higher education including the study of European science. The college built a laboratory, a museum and an observatory. It published science books and the college's periodical named Dig-Duridarshan carried articles on science. One of its most outstanding teachers, John Mack (1797-1845), delivered popular science lectures accompanied by practical demonstrations. The lectures, probably the first public demonstration of modern science in India, used to be attended by students and other members of the society<sup>3</sup>.

Raja Rammohun Roy (1772-1835), a great social reformer and regarded as the father of modern India, was one of the earliest exponents of scientific outlook in the country. He worked relentlessly for removing the prevailing unscientific beliefs in Bengal and rest of the country like dividing the society on caste lines and the practice of Sati that is widowed woman immolating herself on her husband's funeral pyre. He strongly argued for narrowing the 'gap in attitude towards science and technology between India and Europe'. In

his historical letter written in 1823 to Lord Amherst, the then Governor General of British India, wrote that the government should 'promote a more liberal and enlightened system of education embracing mathematics, natural philosophy, chemistry and anatomy with other useful sciences'<sup>4</sup>.

Henry Louis Vivian Derozio (1809-1831), who taught at the Hindu College, attempted to persuade his students to imbibe the spirit of rationalism. The Hindu College was established in 1823 in Kolkata, which was later renamed as the Presidency College. He strongly advocated learning through discussion and debate. He succeeded in inculcating the ways of rational critical inquiry among his followers (who later came to be known as Young Bengal) and his influence remained visible long after his death<sup>5</sup>.

Raja Rammohun Roy's attempts for spreading a rational outlook in the country were taken forward by a number of accomplished individuals like Rajendralal Mitra and Ramendrasunder Trivedi. Rajendralal Mitra (1822/23-1891), the first modern indologist of Indian origin and scholar, played a pioneering role in preparing the ground for spreading the spirit of science. As S. K. Saraswati pointed out Rajendralal Mitra was the first "to challenge the sanctity of tradition, break away from its entangling meshes and establish the need for scientific objectivity in Indian historical thinking"<sup>6,7</sup>.

Ramendrasunder Trivedi played a very important role in science popularization in the late-nineteenth century. His influence could be gauged from the fact that Satyendra Nath Bose, the celebrated Indian physicist and who made pioneering effort in communicating science in the vernacular acknowledged that it was Trivedi's staunch commitment to writing and reflecting on science in the vernacular served as a guideline for establishing the *Bangiya Bigyan Parishad*<sup>8</sup>.

In the 19th century efforts were made to translate science books in the vernacular in different parts of the country. Master Ramchandra (1821-1880), a well-known mathematician and a teacher of science in the Delhi College (later renamed as Zakir Hussain College)

did a pioneering work by translating mathematics and science books into Urdu for the Vernacular Translation Society established in 1843. Master Ramchandra was a mathematician of repute and his book entitled "On the Problems of Maxima and Minima" with an introduction by Augustus de Morgan was published in London. The work initiated by Master Ramchandra's work was expanded to a great extent by his illustrious student Munshi Zakaullah (1832-1910). Translation of science books and writing of popular science articles were taken up in other Indian languages<sup>9</sup>.

Father Eugene Lafont (1837-1908), of the St Xavier's College at Kolkata established in 1860 played a pioneering role in creating public interest in science and promoting science education in schools and colleges. Father Lafont joined the St Xavier's College on 7 December 1865 and he gave his first public popular science lecture-cum-demonstration on 18 September 1868<sup>3</sup>. Jagadis Chandra Bose, often regarded as the first modern scientist of India was the student of Father Lafont.

In 1876, the Indian Association for the Cultivation of Science (IACS) was established at Kolkata by Mahendra Lal Sircar (1833-1904). The establishment of the IACS was a milestone in the history of scientific research and science popularization in the country. It was the first scientific research institute established by Indians. The initial activities of the IACS were confined to organizing popular science lectures. Father Lafont, who also played an important role in founding the institute, organized the first course of lectures in 1887 and which continued till 1893. Among others who delivered popular science lectures at the IACS were Mahendra Lal Sircar, Asutosh Mookerjee (1864-1924), Jagadis Chandra Bose (1858-1937), Pramatha Nath Bose (1855-1934) and Nil Ratan Sarkar (1861-1943)<sup>10</sup>.

The example of IACS inspired others to take up the cause of science popularization. The Dawn magazine, under the aegis of the Dawn Society established by an eminent educationist Satishchandra Mukherjee, took up the task of communicating scientific ideas by publishing popular science articles. Among the people who were associated with the Dawn Society were Jagadis Chandra Bose, Prafulla Chandra Ray, Ramendrasundar Trivedi and Nilratan Sarkar<sup>11</sup>.

The example of IACS inspired Ruchi Ram Sahni of the Government College, Lahore in undivided India to establish the Punjab Science Institute (PSI) in 1885. Sahni later recalled that the first idea of such institute was originally conceived by his teacher at the Government College J. C. Oman but the idea took shape only after Sahni came to Kolkata and experienced the activities of the IACS. Sahni himself delivered more than 500 popular science lectures under the aegis of the Punjab Science Institute at Lahore and other smaller towns and villages. The lectures, which were often accompanied by experimental demonstrations, were organized in open spaces. The expenses for organizing the lectures were met by small fees charged from the audience. Sahni inspired many college teachers to actively participate in the activities of PSI<sup>12,14</sup>.

In 1913, Vigyan Parishad Prayag was established in Allahabad for popularization of science in Hindi. A popular science magazine called Vigyan (Science) was started in 1915 by the Parishad and which is being continuously published since then. Among the activities undertaken by the Parishad included publication of science books and organization of popular science lectures. Many of the well-known names in Hindi science communication were directly or indirectly inspired by the Parishad<sup>15</sup>.

Small groups of science societies came into existence in different parts of the country which held discussions on science subjects but the reach of these activities was quite limited and were confined to those who were associated with these societies. There was no organized attempt for science popularization on a large-scale<sup>16</sup>.

In 1914, the Indian Science Congress was established in Kolkata. The establishment of the ISCA was the result of the initiatives undertaken by the two British scientists J. L. Simonsen and P. S. MacMahon for creating a national platform for interaction among the scientific workers in the country. Since its inception the ISCA recognized the need to spread the messages of science amongst the general public<sup>17,19</sup>.

Three science Academies were established before India's independence namely the National Academy of Sciences of India at Allahabad (1930), the Indian Academy of Sciences at Bengaluru (1934) and the National Institute of Sciences of India (1935), now Indian National Science Academy, first established in

Kolkata and later shifted to New Delhi. In addition to the national science academies many scientific societies were formed for example Indian Mathematical Society (1907), Institute of Engineers (1920), Indian Botanical Society (1921), Indian Chemical society (1924), Indian Medical Association (1928), Indian Physical Society (1935), Entomological Society of India (1938) and Indian Anthropological Society (1941). In many ways the academies and the scientific societies promoted the cause of science popularization<sup>20</sup>.

The cause of science popularization was taken up in real earnest in post-independent India under the leadership of Pandit Jawaharlal Nehru, India's first Prime Minister. Nehru emphasized again and again the need to spread the spirit of science or scientific temper, as he called it, in the country. He believed that, "It is the scientific approach, adventurous and yet critical temper of science, the search for truth and new knowledge, the refusal to accept anything without testing and trial, the capacity to change previous conclusions in the face of new evidence, the reliance on observed facts and not on pre-connected traditions, the hard discipline of the mind etc—all this is necessary, not merely for the application of science but for life itself and the solution of its mundane problems"<sup>21</sup>.

The Scientific Policy Resolution (SPR) No.131/CF/57 adopted by the Indian Parliament on 4 March 1958 reiterated Nehru's vision by stating 'it is only through scientific approach and method of science and use of scientific knowledge that amenities (both material and cultural) and services can be provided to every member of the community.' Nehru's vision was also reflected in subsequent science and technology policies (Technology Policy Statement 1963, Science and Technology Policy 2003 and Science, Technology and Innovation Policy 2013).

Scientific temper was incorporated as one of the Fundamental Duties of every citizen of India through an amendment in the Indian Constitution through an amendment in 1976: 'to develop the scientific temper, humanism and the spirit of inquiry and reform' [Fundamental duties of every Indian citizen vide Part IV-A, Article 51-A (h)]<sup>22</sup>.

Science museums and centres were visualized as an important means of science popularization in the

country<sup>23-25</sup>. The creation of science museum was started in 1954 when a small museum was set up by V. P. Beri at the Birla Institute of Technology and Science at Pilani, Rajasthan. It contained exhibits on art, archaeology, botany, zoology and agriculture. After two years this museum was dismantled for building up a much bigger and better one. The new museum covering a space of about 10,000 square feet was inaugurated in 1958. It was an industrial museum. The museum still survives and it is considered as one of the best university museums in the country. In 1956, K. S. Krishnan, Director of the National Physical Laboratory (NPL), New Delhi, brought in R. Subramanian for setting up a nucleus science museum in NPL. Subramanian, who earlier served as a Curator for Chemical Conservation in the Government Museum in Chennai (then Madras), set up the museum covering a space of 3000 square feet. Among other exhibits the museum displayed a crystal collection donated by Pandit Jawaharlal Nehru, the first Prime Minister of India, a small automatic telephone exchange and a 30,000 volts Spark Generator. The museum was closed down in 1960s and Subramanian moved to Kolkata to head the Birla Planetarium, one of the earliest planetariums to be set up in the country. The year 1956 also marked the beginning of the network of science museums and science centres as in this year the Council of Scientific and Industrial Research appointed Amalendu Bose as Planning Officer for the proposed Birla Industrial and Technological Museum (BITM) at Kolkata. With inauguration of the BITM in 1959 the movement of science museums and centres in country started. The second science museum, Visvesvarayya Industrial & Technological Museum (VITM), was established in Bengaluru in 1965. An autonomous society in the name of National Council of Science Museum (NCSM) was established in 1978 with its headquarters at Kolkata and the science museums and centres established by the Government of India were brought under the administrative control of NCSM. There also some science centres outside the umbrella of NCSM.

Planetariums have made important contribution towards advancing the cause of science popularization. In India, the first planetarium to be set up was in New English School, Pune in 1954—the Kusumbai Motichand Planetarium. It was housed in a concrete dome having an approximate diameter of 9 metres. It

had a seating capacity of 100. The Birla Planetarium at Kolkata inaugurated in 1962 was the first major planetarium in India. Mumbai's Nehru Planetarium was established in 1977 and Delhi had its planetarium in 1984. Today there are about 40 planetariums in the country.

In 1980s organized large-scale science popularization efforts were initiated by the Government of India<sup>36,37</sup>. Realizing the need for a coordination agency for conceptualizing, implementing, networking and monitoring science popularization activities in the country the Government of India established the National Council of Science and Technology Communication (NCSTC) in 1982 as a division of the Department of Science and Technology. Among the major activities initiated by the Council were: development and dissemination of popular S&T resource materials, training in S&T communication, coordination with other agencies engaged in science communication, field based programmes, incentive schemes in the form of awards and fellowship for encouraging science communicators and nationwide science popularization campaigns. Vigyan Prasar, an autonomous organization was established in 1989 under the Department of Science and Technology for taking up large-scale science popularization tasks. The Council of Scientific and Industrial Research (CSIR) through its constituent organization National Institute of Science Communication and Information Resources (NISCAIR) has made important contribution in the field of science communication.

Various people's science movement (PSMs) emerged around late 1970s and early 1980s and they redefined the science popularization initiative in the country<sup>34,35</sup>.

The motivations and contexts of science popularization are changing over the ages and they will continue to change in future. Understanding the historical initiatives can help us in tackling the present challenges in science communication that we face today.

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## Remembering Ved Prakash Beri : an artist who created one of the early science museums in India

*V N Dhaulakhandi and Jayanta Sthanapati*

*"Shri V P Beri touched nothing which he did not adorn" – Ramanathbhan Subramanian*

*"The greatest contribution of Shri V P Beri was introduction of artistic elements in exhibits of science museums through well-designed visual support and dioramas" – Saroj Ghose*



*Shri V P Beri at his residence in New Delhi in 2012.*

Museums in India have existed in one form or other for almost two hundred years. The Indian Museum in Calcutta was opened in 1814. Other museums of traditional nature, established during the 19th Century British India, were Government Museum, Madras; Government Museum, Trivandrum; Central Museum, Nagpur; and the State Museum, Lucknow. A dedicated Museum of Industry, the Lord Reay Industrial Museum, which was primarily a display of collections, was established in Pune in 1875. The Indian Museum too had some collection of natural objects. However no modern science museum fully dedicated for display of science and technology exhibits was established in British India.

The Science Museum, London was established in 1857 and after two decades the Natural History Museum, also in London was opened in 1881. World's largest

museum of technology and science, the Deutsches Museum in Munich was inaugurated in 1903. In the United States, the National Museum of Natural History of the Smithsonian Institution in Washington D.C. was opened in 1910. The Air and Space Museum, another important museum under the Smithsonian Institution, and most visited (about 9 million every year) in the world, was opened in 1946. The Japanese National Museum of Nature and Science, set up in Tokyo in 1871, was the first dedicated museum of science and natural history in Asia. India was the second Asian country to have a science museum, but only after her independence.

In early years of 1950s four towering personalities took keen interest in establishing Science Museums in the country. They were Pandit Jawaharlal Nehru, First Prime Minister of India, Syt. Ghanshyam Das Birla, an eminent industrialist, Prof. K. S. Krishnan, a distinguished physicist and Dr. Bidhan Chandra Roy, a renowned physician and the then Chief Minister of West Bengal. With their unconditional support and due to dedicated work of three young enthusiasts, namely, Shri Ved Prakash Beri, Shri Ramanathan Subramanian and Shri Amalendu Bose, three science museums came up in the country. In 1954, Birla Museum was set at Pilani, a small town in Rajasthan. The museum was reopened with more exhibits on science and technology in 1958. A Science Museum at National Physical Laboratory in New Delhi was set up in 1957. The Birla Industrial and Technological Museum was established in Calcutta in 1959.

The NPL Science Museum was, however, closed after demise of Prof. Krishnan in 1961. As a result Shri Subramanian had to move to Calcutta. There he established Birla Planetarium, the first Asian Planetarium in 1962, under guidance and financial support of Syt. M P Birla, another member of the Birla Family. Both Birla Museum at Pilani and Birla Industrial and Technological Museum in Kolkata have been playing great roles in enhancing public understanding of science since their inception. The Birla Planetarium, Kolkata will celebrate its Golden Jubilee on 2 July, 2013.

Name and location of the Science Museums	Year of establishment	Young leaders who developed the science museums and their background	Towering personalities who encouraged the team leaders and supported the projects
Birla Museum, Pilani	1954 (expanded in 1958)	Shri Ved Prakash Beri (Art & Sculpture)	Pandit Jawaharlal Nehru Syt. Ghanshyam Das Birla Syt. Lakshmi Niwas Birla
Science Museum, NPL, New Delhi	1957	Shri Ramnathan Subramanian (Physical Science)	Pandit Jawaharlal Nehru Prof. K.S. Krishnan
Birla Industrial and Technological Museum, Calcutta	1959	Shri Amalendu Bose (Chemistry)	Pandit Jawaharlal Nehru Dr. Bidhan Chandra Roy Syt. Ghanshyam Das Birla

*Modern Science Museums established in India during 1950s.*

From early 1950s industrialist Syt. Ghanshyam Das Birla (1894 -1983) was toying with an idea to develop a science and technology museum in the country. He had strong base in Calcutta, Delhi and also at Pilani. The process of making Pilani ultimately a town of educational institutions began as early as in 1901 with the establishment of a primary school by his grandfather Seth Shiv Narayan Birla (1838-1910). An intermediate collage was established there by Shri G D Birla in 1928 and the Birla Education Trust (BET) was formed, also at Pilani, under his chairmanship in 1929. Then came up, one after the other, a Girls School (1931), a Degree Collage (1943), a Montessori School (1944) and the Collage of Engineering (1946), all at Pilani, under the BET before independence. In early 1950s, a Collage of Arts (1951) and a Collage of Science (1952) were established. Subsequently, both science and engineering collages merged to become the Birla Institute of Technology and Science.

Shri G D Birla at that time engaged Dr. Charles Fabri, a famous art critic of Hungarian origin, to set up a museum at Pilani. As a result, a nucleus of a museum was formed with some specimens of natural history, and a few art objects like miniature paintings, sculptures etc.

In 1952, the trustees of the museum visited the Imperial Institute in London which displayed various exhibits in respect of activities of the British Empire in colonial countries including India. There they found six dioramas on tea garden, rubber plantation, cotton mill, rolling mill, sugar mill and surface colliery very

impressive. With a view to display similar exhibits in the Pilani Museum, they placed an order for duplication of the dioramas with a London based model maker M/s Rendal Page.

Unfortunately, the duplicated exhibits got damaged during transportation from London to Pilani. It transpired to the museum authorities that a huge sum would be needed to get those exhibits repaired by the British fabricators. They, therefore, requested Shri Dhanraj Bhagat, an eminent sculptor and professor of Delhi Polytechnic School of Arts (known as School of Planning and Architecture now) to arrange for repair of the dioramas at Pilani. Prof. Bhagat in turn advised Ved Prakash Beri, a young artist of his collage to accept the challenge.

Shri V P Beri was born on 8 August 1931 at Sialkot in undivided India, which now is under the Punjab province in Pakistan. He completed his collage studies in Delhi. After graduating in science from Hindu Collage, he received a diploma in fine arts, in the field of sculpture, from Delhi Polytechnic School of Arts. In 1955 he began his career in Pilani Museum, as an assistant to Charles Fabri. However, Fabri who was basically stationed in New Delhi, discontinued his association with the project soon. Shri Beri then approached Shri S D Pande, Secretary of the Birla Education Trust and expressed his desire to shoulder the primarily responsibility to give the museum an acceptable shape as was envisioned by Syt. G D Birla. Pandeji valued his promise and discussed the matter with Shri Birla. As a result, Shri Beri was appointed as a

Curator of the budding museum and sent to Europe for a nine month study tour of world famous science museums including Science Museum in London and Deutsches Museum in Munich. The museum project thereafter was monitored by Syt. Lakshmi Niwas Birla, the eldest son of Shri G D Birla.

On his return from abroad in 1956, Shri Beri was fully enlightened and seriously focused on the Birla Museum project. He decided to fabricate all the exhibits of the museum in house and engaged about a hundred local artisans as technicians. He was supported by a group of able supervisors. He deployed Shri N G Singh for fabrication of mechanical parts and Shri M P George for developing electrical circuits. Two imaginative artists Shri G D Ganu and Shri R B Kazi, were in his exhibit development team. He was further assisted by a highly skilled carpenter Shri Ramji Lal.



*Shri V P Beri accompanied Pandit Jawaharlal Nehru and Smt. Indira Gandhi inside a gallery of Birla Museum (1961).*

A fairly large workshop was set up and exhibits, such as, dioramas, panoramas and models were created to matchless perfection. The working models could be operated with just the flick of a hand and a touch of a few buttons. The exhibits covered subject areas like agriculture, irrigation, metallurgy, nuclear science and coal mine; and were also on manufacturing plants or industries like automobile, oil, rubber, tea, sugar, salt, marble etc.

Smt. Rama Beri recently recollected, "Back in those days, resources were limited but despite that, exuberant models were created by the local artisans. These people

had never ever stepped out of their small villages due to lack of transport but they created a model on 'growth of transport system of the world'...wheels, cars, rails, ships and the latest model of airplanes with the minutest of details. For example, a Luxury Ship model had a swimming pool on the deck with human figures sitting on reclining chairs with umbrellas!"

As the museum was growing day by day a need was felt to house it in its own building of specific design to match its requirements. The majestic Birla Museum building, as we see now, was designed by renowned architect M/s Stien and Polk of Calcutta and its construction was completed in 1964, in the premises of Vidya Vihar, the celebrated Educational complex of Pilani. Large number of new exhibits along with the old ones were installed in this building. A number of Artists, Interior decorators and Horticulturists were engaged to make the inner and outer environment of the building graceful. To add to the beauty of the Birla Museum, a sculpture called the 'Cosmic Man' was installed at the entrance to welcome everyone. It was developed by a California based sculptor Shri Kewal Soni, who followed a design conceived by Shri Beri.

Shri Lakshmi Niwas Birla donated his personal collection of the most expensive master paintings and artifacts. An Art Gallery was specially designed on the first floor of the building to accommodate this collection. Science and technology exhibits of the museum were on metallurgy, transport, space, chemistry, textiles, agriculture, mining, arms, irrigation, nuclear science and so on.

Besides being a very creative artist, Shri Beri was an excellent administrator. The Birla Museum reflects his energy - well maintained and organized, and it looks like a place of worship rather than a place of Industry and Technology. He left no stone unturned to maintain these high standards. Only the best always...no compromises! He was a man of few words, he dealt with his office staff in an extremely unique way, with different coloured stationery for different people...the colour of the paper would represent the concerned person! His office colleagues respected and loved him fondly despite his strict nature.

Since 1957, Shri Beri, Shri Bose and Shri Subramanian had maintained close professional contacts with each



*The present building of Birla Museum.*



*'Cosmic Man'-a sculpture on the foreground of Birla Museum.*



*Indoor water-body exhibit of Birla Museum.*



*Diorama of a Blast Furnace.*



*V P Beri and Jayanta Sthanapati during an interview of the former in New Delhi (2003).*

other, although their planning strategies of science museum exhibits differed greatly.

Prof. Ramanathan Subramanian during a conversation with one of us had praised Shri V P Beri with following words -- "I have known Mr. V P Beri right from the inception of his career in the mid-fifties in the domain of museology. Sitting at the hub of activities of the Birlas, he had set up not only a Haveli Museum (Family Museum), but was also instrumental in visualizing a Central Museum covering the areas of physical science and engineering. Mr. Beri as a man of art was very aesthetic in many things that he did or planned. He was also a person of great human qualities and discussed about exhibits, dioramas without mincing words. He would appreciate without any reservation good presentation and works. There is a saying "Nihil quod

tetigit non ornavit" (He touched nothing without embellishing it). Truly, this applies to Mr. V P Beri. His office, his instruments and the exhibits were all spic and span all the time. The Museum World will very much miss this personality."

While answering to a question on the unique or greatest contribution of Shri V P Beri in science museum activities, Dr. Saroj Ghose, former Director General of National Council of science Museums wrote, "Exhibits in art and archaeology museums are intrinsically artistic in nature. In contrast, science museum exhibits, mostly machines and equipment, did not have attractive look as Victor Danilov, the long time Director of Chicago Museum of Science & Industry termed it as 'ugly duckling'. In my opinion the greatest contribution of V P Beri was introduction of artistic elements in otherwise ugly exhibits of science museums through well-designed visual support and dioramas. If not for anything else, Shri Beri will ever be remembered for outstanding dioramas creating 3D perspective even in small restricted space, with simple ingenious animations. ... Both BITM and VITM were initially developed with so-called sobre approach in display, but at a much later stage, new generation of exhibition officers in NCSM came up with brilliant colourful artistic displays based on their own imagination. In my opinion, Shri Beri's concept of display was ultimately vindicated in the science museums of India."

In 1996, Shri Beri retired from Birla Museum and became Director of K K Birla Academy of Scientific, Historical and Cultural Research in New Delhi. Dr. V N Dhaulakhandi took over charge of this great science museum from him. Dr. Dhaulakhandi had started his career in Birla Museum as an Education Officer in 1982. He narrates an interesting incidence about his selection by Sri Beri, "I met him for the first time in Decemebr 1981 when I was called for interview. This interview was quite interesting as I was called for 5 days. On first four days I was asked to observe the working of Workshop Division, Upkeep Division, Maintenance Division and Establishment Division. On fifth day Mr. V P Beri called me in his chamber, and the only question he asked was 'When can you join?' I was speechless as I had entered in the office for a formal interview. Later I realized that during first four days he



*K K Birla while discussing an issue with V P Beri and V N Dhaulakhandi (2008).*

observed me in various departments, he found that I may be suitable for the Museum and therefore offered me the job. I joined the Museum in April, 1982."

In 1960, Shri V P Beri married Smt Rama Beri, who came from a bureaucrat background and had earned BA and BEd degrees from Delhi University. Their three daughters and one son are all well educated and well placed. In Mrs. Beri's words, "Shri Beri was a soft spoken and very kind hearted gentleman. His firm square jaw line not only made him handsome but also a man of determination and confidence. The most loving father and a great husband who was adored by all...Mr.Beri! Last but not the least, adding the most important feather in the cap, if one goes through his 50 year old papers and files (income tax documents, medical bills, job offer letter etc) even today, one will see them compiled meticulously, and neatly labeled with details...that's Mr. Beri for you. Full of precision, perfection, concern, love and affection for every little thing he did and for every person he cared for...his family, friends and colleagues. His friends called him a Cute Curator...as in Cute Creator.. like Lord Vishnu."

Shri Ved Prakash Beri passed away peacefully at his home in New Delhi in the wee hours on 9 December 2012. The science museum fraternities will always remember him.

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## Global Effort for Polio Eradication : India on the Verge of Being Declared Polio Free

*Shivaprasad M Khened*

India is now on the verge of achieving an unprecedented milestone of being a polio free nation for two full years. The last lone known case of wild polio, with the onset of paralysis, detected in India was in the year 2011 in a two year old girl in Panchla block of Howrah, on 13<sup>th</sup> January 2011<sup>1</sup> and ever since India has

This article focuses on the fascinating history and development of the polio vaccine and chronicles the struggles that went behind this largest public health initiative in history – Global Eradication of Polio. It gives an insight into the global efforts to eradicate polio against great odds with special emphasis on India.

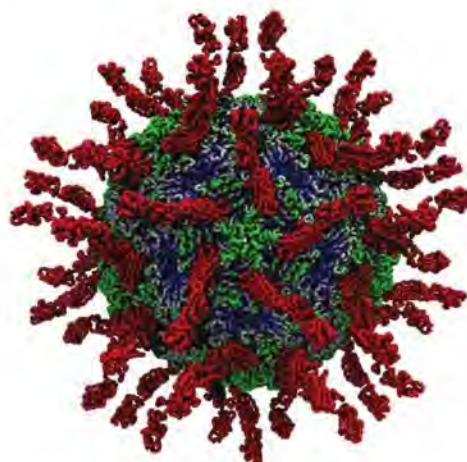


*Two year old Rukhsar Khatoon with her mother.*

been a polio free nation. If India continues to maintain its current record for another year, it would be permanently declared as a polio free country by the World Health Organisation (WHO). This outstanding achievement is seen as the result of persistent and focused effort and unprecedented collaboration among scientists, administrators and international partners. Polio eradication campaign in India has combined cutting edge research on vaccines with an extensive implementation scheme and an intensive monitoring – cum-follow up plan. The scheme has covered every nook and corner of this vast and diverse country and is backed up by effective campaigning by public and private agencies, a strong political desire and relentless surveillance. The programme has received the highest level of social and political commitment which is reflected in the resource allocation and the continuous ground level actions to identify and reach out to the most vulnerable children while ensuring maximum reach and optimum use of available vaccines under the guidance of top national and international experts.

### What is Polio

The word *poliomyelitis* (Paralytic poliomyelitis), meaning, Polio in short, the medical term used to describe the effect of poliovirus (PV) on the spinal cord, is derived from the Greek roots for gray (polio) and marrow (*myelon*). It describes the tissue most commonly affected in the spinal cord that leads to the symptomatic manifestation of paralysis<sup>2</sup>. Polio is a faeco orally transmitted disease caused by an intestinal virus that may attack nerve cells of the brain and spinal cord. Research in medical diagnostics, biomedical research, understanding the genome etc, especially in the later part of the twentieth century, including the Human Genome<sup>3,4</sup> has helped the human society in the development of vaccines which have helped us in combating this deadly pathogen. The genome of polio virus is comparatively small yet it is packed with requisite information to make it a formidable pathogen<sup>5</sup>.



*Electron Microscopy Image of the Poliovirus.*

Poliovirus, a member of the enterovirus subgroup are

the transient inhabitants of the gastrointestinal tract, are stable at acid pH and have an RNA genome, which is 7411 nucleotides long<sup>6</sup>. There are three poliovirus serotypes (P1, P2, and P3) and there is minimal heterotypic immunity between the three serotypes. It can rapidly be inactivated by heat, formaldehyde, chlorine and ultraviolet light.

Polio can be spread through contact with contaminated feces or through airborne droplets in food or in water. The virus enters the body through nose or mouth, and then travels to the intestines where it incubates. Next, it enters the bloodstream where anti-polio antibodies are produced. In most cases, this stops the progression of the virus and the individual gains permanent immunity against the disease<sup>7</sup>. Polio manifests in three ways; mild polio, non paralytic polio and paralytic polio. The symptoms of Polio include fever, headache, sore throat, and vomiting. Some of the Polio victims develop neurological complications, including stiffness of the neck and back, weak muscles, pain in the joints, and paralysis of one or more limbs or respiratory muscles. In severe cases Polio may prove to be fatal as a result of respiratory paralysis.

Polio was feared for it was wrongly perceived that anyone who contracts the polio virus is certain to be paralyzed and may even die. This is contrary to facts and in most infections caused by polio there are few distinctive symptoms of Acute Flaccid Poliomyelitis, AFP in short. In fact, 95 percent of everyone who is exposed to the natural polio virus won't exhibit any symptoms, even under epidemic conditions since the human immune system is capable of protecting us from this pathogen<sup>8</sup>. Only about 5 percent of infected people will experience mild symptoms, such as a sore throat, stiff neck, headache, and fever, often diagnosed as a cold or flu. Muscular paralysis has been estimated to occur in about one in every 1,000 people who contracts the disease<sup>9</sup>.

### Early accounts of Polio

One of the earliest written accounts of Polio is that of the Pharaoh, Siptah, who ruled ancient Egypt from 1200 BC to 1193 BC. It is said that Siptah was stricken with paralysis disease as a young boy. There is also a myth associated with the incident. However the oldest identifiable reference to the prevalence of Polio once

again comes from Egypt in the form of an Egyptian Steele, a stone engraving about 3000 years old, which describes a priest with a withered leg, suggesting that



*Egyptian Steele, a stone engraving about 3000 years old.*

polio existed for thousands of years<sup>10</sup>. Many references to Polio also appear in the Bible in which polio is translated as palsy. In English language translation of the Bible, the word palsy is used instead of the word “paralysis”, which is derived from the French word *paralésis*, meaning paralysis. This was shortened to *palesie*, which appeared as palsy in the King James Version of the Bible in the 16<sup>th</sup> century.



*Sir Walter Scott.*

Sir Walter Scott (1771-1832), a Scottish novelist and

poet, wrote about his own case of Polio<sup>11</sup>. However it was only in the year 1789 that a proper description was given for this disease by the British physician Dr. Michael Underwood. He was the first person to give the first known clinical description for polio which he called the "*debility of the lower extremities*"<sup>12</sup>. He further stated that polio disease was responsible for the hindrance of the lower extremities in children that was recognizable as poliomyelitis.

Dr. Jacob Von Heine, an orthopedist from Germany was the first person to conduct systematic investigation of polio. He developed the theory that this disease may be contagious. He published a 78 page monograph in 1840 which describes the clinical features of Polio and also the symptoms associated with it. Dr. Heine further suggested the involvement of the spinal cord associated with this disease. Unfortunately due to the limited medical knowledge of that time and also because of the sub microscopic nature of the polio virus Heine and others could not understand the contagious nature of the disease. Based on his study the illness associated with Polio was recognized as a clinical entity. It is in recognition of this that Poliomyelitis is often referred to as *Heine-Medin* disease, after the works of Heine and Karl Oskar Medin.

During the 1905 polio epidemic in Sweden, Dr. Ivar Wickman, Swedish pediatrician, was the first to clearly show the infectious nature of polio. In the year 1907, Wickman also categorized the three different clinical types of Polio namely poliovirus serotypes P1, P2, and P3. This was soon followed by the isolation of the poliovirus in laboratory monkeys in 1908 by Karl Landsteiner, Viennese immunologist, who was awarded the Nobel Prize in Physiology and Medicine in 1930 for his discovery of the human blood groups<sup>13</sup>, and his associate Evvin Popper in Vienna. They also discovered that bacteria could not be found in spinal cord tissues of infected human and they therefore thought that perhaps bacteria were not the causes for the disease. This led them to suggest that virus was the causative agent of Polio. They further experimented by injecting suspensions from the spinal cord of a diseased 9-year-old boy into rabbits, guinea pigs, mice and monkeys. Only the monkeys showed signs of disease. They ground up the spinal cords of children who died of polio and injected the material into

monkeys. Soon the monkeys developed the disease. They also observed that no bacteria were found in the monkeys and their nervous system changes resembled those of rabies. Based on their findings, Landsteiner suggested that the disease has a viral etiology. He then sent fragments of a spinal cord from a 13-year-old child afflicted with poliomyelitis to the Pasteur Institute in Paris. Poliovirus was shown to be a filterable virus that could spread along nerves and be transferred between monkeys.

The discovery of the virus-causing poliomyelitis was immediately accepted. In the following years Simon Flexner and Paul Lewin working at the John Hopkins University in Maryland, confirmed Landsteiner and Poppers findings<sup>14</sup>. This was of great importance since scientists could now attempt to find a vaccine to stop the spread of this disease. By 1909-10, the main focus of polio research had shifted to the Rockefeller Institute for Medical Research in New York City. The polio research at the institute was lead by Dr. Simon Flexner and his team. Indeed, 1910 was a landmark year for polio; the Congress of American Physicians and Surgeons devoted more attention to polio that year than to any other subject. In Flexner's lab the poliovirus seemed to only infect the nervous system, but was also present in a small number of non-neural sites, particularly the upper nasal area after direct inoculation. Polio thus seemed to be a respiratory infection with the virus spread by infected droplets followed by direct nervous system invasion via the nerves in the nose. This nasal-nervous system model dominated how polio was approached until the late 1930s.

During the next course of the research one of the first questions to be answered was whether just one particular virus caused polio or if there was more than one kind of virus and how this was transmitted. Research on this question took several years. But it was finally proved there are just three strains or types of virus that cause the ailment. This gave hope that a vaccine could be produced to prevent polio. Sabin was the first researcher to show that polio virus was present in digestive system as well as brain and spinal cord.

The study and understanding of how polio was transmitted from one person to another was the next important step towards better understanding of the

spread of this disease for a possible vaccine. Flexner and Lewis during their initial study of this disease were of the opinion that polio was spread directly from the nose to the brain. They introduced washing from nose and throat of the infected people into the monkey's nasal passages. Monkeys developed polio so they concluded that this was the mode of transmission. This however was not the case. Unfortunately for the next 20 years or so people believed that this was the way by which polio was transmitted.

A hint to the true means of transmission of this disease was found in 1912 when Swedish researchers discovered polio virus in the contents and walls of the human small intestine. It was not until 1941 that Albert Sabin showed that polio virus was not present in the nasal membrane of patients who died of polio. He demonstrated the presence of the virus in the digestive tract as well as brain and spinal cord.

Polio struck fast and there was no known cure for this crippling disease and no one was spared of this dreaded disease, not even the rich and powerful, including the then President of USA Roosevelt. Polio crippled its victims for life. The scene of people hobbling on crutches, rolling in wheelchairs, or lying immobile in giant iron lungs, across the globe was one of the most common scenarios and the number of people who suffered from this disease increased every year. No one knew for sure the exact mechanism of polio's transmission and therefore it was very common then to place many areas under strict quarantine when cases of the disease began to manifest themselves. Only the fear surrounding AIDS now can rival the feelings people had about polio in the first half of the twentieth century.

### **Polio Eradication**

The first reported outbreaks of polio in Europe were reported in the early 19th century, and outbreaks were reported in the United States a few years later. For the next hundred years, epidemics of polio were reported from developed countries in the northern hemisphere each summer and fall. These epidemics became increasingly severe, and the average age of persons affected rose, which increased both the disease severity and number of deaths from polio. Polio reached a peak in the United States in 1952, with over 20,000 paralytic

cases. However the polio incidence fell rapidly following introduction of effective vaccines. The last case of wild-virus polio acquired in the United States was in 1979.

Only once in human history have we witnessed the total eradication of a dreaded disease, and that was smallpox more than two decades ago. The humanity now stands on the brink of a second major triumph to rid the society of Polio which has been achieved through the "global eradication of polio" campaign spearheaded by the WHO with support from Rotary International and several other governmental and non governmental agencies. As we are inching very close to this remarkable milestone it is time to look back on some historically significant developments that have led us to this remarkable collective human endeavor.



*Franklin D Roosevelt.*

Franklin D Roosevelt, President of the United States from 1932 to 1945, a polio victim, popularly known as FDR, declared a War on Polio during his presidency tenure. He constructively used the tremendous resources of postwar America to combat the polio menace and aided the scientific community to develop a vaccine that could help prevent polio. Roosevelt wore heavy steel braces on his legs and walking was difficult for him. Most of his time was spent in a wheelchair. Roosevelt contracted the poliomyelitis paralysis on Aug 10, 1921 at the age of 39 years while vacationing at his Canadian summerhouse on Campobello Island, during one of his swimming outings.

Warm Springs is the most famous of Georgia's seven known warm springs and the water at the warm spring is believed to contain some magic therapeutic properties because of the presence of some beneficial mineral in its waters. The native Indian habitants believed that the water at the Georgia Springs could be beneficial as a medical cure for several diseases. It was believed that the warm water springs contained minerals and that the constituents of these minerals in the water at the spring could treat various diseases. For the local Indians, the springs were probably a place of healing where the Indians of all tribes were allowed to bring their sick and wounded to drink the waters and bathe in the mud<sup>15</sup>.

Recognizing the potential of the location as a great tourist resort, in the year 1923 Warm Springs Company was formed with George Foster Peabody as its president. One of beneficiaries of the magic healing properties of the warm springs of Georgia was a young civil engineer from New York, Louis W. Joseph. He had been greatly helped by swimming in the pool at Warm Springs. On learning about this incident and about the benefit that the warm springs could provide to polio victims, Peabody, who had befriended Roosevelt when FDR had been Secretary of the Navy and an unsuccessful vice-presidential candidate, informed Roosevelt about the incident and asked Roosevelt to try if this could help him. Roosevelt came to Georgia in 1924 and discovered that a swim at the warm springs served as a hydrotherapy and he was able to easily move his lame legs under water. Roosevelt remained closely tied to the Georgia springs for the next 21 years, until his death in 1945<sup>16</sup>.

A local news paper published an article that Georgia's Warm springs have provided therapeutic relief to Roosevelt, who by then was already very famous. This local news article was soon picked up and reprinted nationally. Soon thereafter other polio victims began to arrive at the old resort for treatment and stayed in the adjacent cottages. The polio activities overshadowed the vacation resort uses for which the company was formed and therefore, on the insistence of Roosevelt, Warm Springs Foundation was established in 1925 for the study and after-treatment of infantile paralysis (polio). Roosevelt became the head of the foundation and Peabody one of the four trustees. The new Foundation had two objectives namely to use the natural facilities of Warm Springs and the skill of an able, carefully-selected professional staff for the direct aid of patients and to pass on to the medical profession and to hospitals throughout the land, useful observations or special methods of proved merit resulting from this specialized work, which might be applied elsewhere.

Unfortunately, notwithstanding the noble cause of the Foundation, it received protests from regular resort guests who felt their sharing of the facilities with the patients of Polio would endanger them to the disease. During this period there was lot of confusion and misunderstanding about polio. In order to allay the fears of the regular guests, Roosevelt, on his own, built a small treatment pool a distance from the public pool, for the exclusive use of the polio patients.

Roosevelt, in the year 1926, invited Dr. LeRoy W. Hubbard, an orthopedic surgeon of the New York



*Little White House.*

State Health Department, to conduct a medical study on the effects of warm water on polio victims. Dr. Hubbard observed 23 patients for a period of time and then wrote a detailed report indicating that each patient had seemed to improve, and some showed marked improvement. This convinced Roosevelt of the benefits for treating polio and “swimming his way to health.” As Peabody once said, “Without Warm Springs, Franklin Roosevelt could never have become the President.” Roosevelt even after becoming the President of the United States continued to visit the warm springs. The cottage where he stayed during his visit became the “Little White House.”

The Georgia Warm Springs Foundation dedicated itself to the conquest of polio. Through its fund raising “President’s Birthday Balls” and the “March of Dimes” treatment was provided to polio victims. When the Salk and Sabin polio vaccines virtually eliminated polio, the need for the Foundation was greatly lessened. The Little White House and other properties were willed to the Foundation by President Roosevelt. In 1947, a memorial was dedicated to him at the site, and has been visited by millions of people.



*'President's Birthday Balls' poster.*

In 1932, Roosevelt was elected President. The fact that the disease had affected a man in the White House seemed to arouse public's interest. The trustees of the Georgia Warm Springs Foundation decided money could be raised for the foundation by holding dances in cities across the nation on the President's birthday, January 30. More money was raised than was needed for Warm Springs, so it was used for scientific research. In January 1938, alarmed by decades of worsening polio

epidemics and the terrible toll the virus was taking on America's young, President Roosevelt established the National Foundation for Infantile Paralysis. The Foundation emphasized the nationwide significance and non-partisan character of the polio crusade. Roosevelt believed that people could solve any problem if they worked together. Comedian Eddie Cantor coined the phrase “March of Dimes” (playing on the popular newsreel feature “The March of Time”),



*The March of Dimes - polio eradication campaign.*

appealing to radio listeners all over the country to send their dimes directly to the White House. The campaign to start with received lukewarm response but within weeks of launching the campaign it became immensely popular and White House was flooded with loads of Dimes thus proving to be hugely successful. The National Foundation officially changed its name to the March of Dimes in 1979<sup>17</sup>. The money collected from this campaign was put to proper use by financing medical research in the leading universities and medical schools to develop a polio vaccine. This research has led, step by step, to the ultimate victory over polio. The March of Dimes occupies a unique place in American history. Its efforts to provide care for the victims of polio while aggressively working to develop vaccines against it, represents the first large-scale, nationwide biomedical initiative, led by a charitable organization. It also helped make the volunteer movement an integral part of the fabric of American life. March of Dimes investment has also been made in other research fields in science, which include support to 11 Nobel laureate scientists whose original work was supported by grants from March of Dimes.



*J.F. Enders, T.H. Weller and F. C. Robbins were jointly awarded the Nobel Prize.*

### Early efforts in the development Polio Vaccines

The first great hope of developing polio vaccine emerged in 1934-35. Dr. Marice Brodie developed an inactivated polio vaccine and it was soon followed by the rival group headed by Dr. John Kolmer who developed an attenuated version of the polio vaccine. The success though was short-lived. Their hasty uses of vaccines in parts of US proved ineffective and in several cases were fatal. This experience left polio researchers hesitant to attempt another polio vaccine for the next 20 years.

An important new era in the history of polio vaccines began when a short paper was published in the journal *Science* by J.F. Enders, T.H. Weller and F.C. Robbins, of Boston Children's Hospital and Harvard Medical School. They were jointly awarded the Nobel Prize in Physiology or Medicine in 1954 "*for their discovery of the ability of poliomyelitis viruses to grow in cultures of various types of tissue*"<sup>18</sup>.

Their paper described the means of solving the long-standing problem of culturing the poliovirus in test tubes using non-nervous tissues. The essence of their discovery is described in their Nobel Prize acceptance speech<sup>19</sup>. Their discovery finally provided a method to cultivate poliovirus in vitro. This landmark discovery

finally opened the door for the development of a practical polio vaccine.

In 1951 a method of providing passive immunity to polio was first tried in North America. During the course of this experimentation it was discovered that the small amounts of virus that entered the bloodstream could be overcome by a small amount of poliovirus antibodies. Poliovirus antibodies contained in gamma globulin could thus be used to neutralize poliovirus infection over a limited period of time. Further studies showed antibodies against polio are formed in the blood of the victim. That's why a person who has suffered an attack by one strain of virus is immune to that strain thereafter. Subsequent works made it apparent that a practical vaccine for the prevention of polio could be produced.

Dr. Jonas Salk was born to the Russian-Jewish parents, and attended the medical school in New York University. He spent a year researching the recently discovered influenza virus. His technique succeeded and influenced his later work on polio: He later said "The principal that I tried to establish was really that it was not necessary to run the risk of infection, which would have been the case if one were to try to develop an attenuated or weakened poliovirus vaccine. And so it seemed to me the safer and more certain way to

proceed. That if we could inactivate the virus that we could move on to a vaccine very quickly.<sup>20</sup>

Dr. Salk while working at the University of Pittsburgh undertook a major effort to sort out 196 known strains of poliovirus into three immunologically distinct types and categorized them as strains I (161 strains), II (20 strains) and III (15 strains). In 1946 he became assistant professor of epidemiology at Michigan. By 1951, based



*Jonas Salk was the first to develop a successful polio vaccine.*

on his earlier work of developing an inactivated influenza vaccine, and his experience with the poliovirus type project, coupled with the work of others studying poliovirus immunity in monkeys, Salk suggested that an inactivated polio vaccine might stimulate active immunity in humans. He developed the polio vaccine by cultivating three strains of the poliovirus separately in monkey tissue.

The virus was separated from the tissue, stored for a week, and killed with formaldehyde. He then conducted tests to make sure that the virus was dead. He proved that a series of three or four injections with the killed virus vaccine were required to confer polio immunity. The works of Dr. Andrew J. Rhodes, a leading virologist from England with a special interest in polio, were of special significance to Salk in the development of his vaccine. By 1951, Rhodes' research team was able to grow all three types of poliovirus in a variety of tissues. Salk used the method of growing poliovirus in different tissues in the development of a polio vaccine. This vaccine came to be known as the Salk vaccine. Salk tried his vaccine by first injecting himself and his family to infuse a sense of confidence among the public. He then

proceeded to administer the vaccine to residents of an institution for disabled children near Pittsburgh<sup>21</sup>. The encouraging results of the trial were published in March 1953. It was around this time that Dr. Leone Farrell developed the "Toronto technique" to produce bulk quantities of poliovirus fluids in large bottles. This development paved the way for mass production of Salk vaccines.

Encouraged by Salk's results, in July 1953 the National Foundation for Infantile Paralysis asked Connaught Medical Research Laboratories (Aventis Pasteur Limited) to provide all the poliovirus fluids required for an unprecedented polio vaccine field trial in the US. Some 3,000 litres of bulk poliovirus fluids produced by Connaught were shipped to two major pharmaceutical companies, Parke Davis and Eli Lilly in the US to be inactivated and processed into a finished vaccine. Before being released for the field trial, each batch of vaccine had to pass through a battery of tests, first by Connaught, then each company, Salk's lab and the US government. Amidst intense publicity, the first children were given the new polio vaccine on April 26, 1954. The field trial was one of the largest medical experiments in history, at that time, and involved an elaborate tracking of some 1,800,000 children in the age group of 5-8 years. They were either given the vaccine, or were simply observed to see if they contracted polio or not. The results were dramatic. Cases of polio fell spectacularly in the vaccinated test groups. In 1955, the government quickly granted permission for the vaccine to be distributed to the children of US. On April 12, 1955, the highly anticipated clinical trial results turned into a major media event, perhaps the biggest in medical history. "SALK'S VACCINE WORKS!" screamed the headlines. Dr. Thomas Francis, director of the trial, reported that the vaccine was 60 to 80 per cent effective against paralytic polio. He and Salk stressed that the vaccine was good, but it was not perfect.

The success though was not long lived. Suddenly, on April 25, 1955, the Salk vaccine euphoria was shattered when the first of a total of 205 cases of polio associated with vaccine made by Cutter Laboratories in California were reported. The problem was traced to incomplete inactivation of some virus particles, which was soon corrected. Since then the vaccine has been highly effective, with a 70 - 90% protection rate. The Salk vaccine is given in two intramuscular injections spaced

one month apart and is to be followed by boosters every 5 years.

Albert Bruce Sabin, born in 1906 in Poland, then a part of Russia, to escape racial persecution, immigrated with his family to the USA in 1921. He graduated from New York University in 1928. In 1935, he joined the staff of Rockefeller University before moving in 1939 to Cincinnati Children's Hospital to conduct research on viruses. His experience of working as a consultant to the army during World War II, during which time he isolated the virus of sand fly fever, and also helped in developing a vaccine against dengue fever, benefitted him in developing a live oral polio vaccine.

Sabin showed that poliovirus first invaded the digestive tract and then the nervous system. In 1957, in an effort to improve upon the Salk vaccine, he began testing a live, oral form of vaccine in which the infectious part of the virus was inactivated (attenuated) and not killed, as was the case in Salk vaccine. He developed a live but attenuated oral vaccine that not only proved to be superior in administration, but also provided longer lasting immunity than the Salk vaccine. The killed-virus vaccine of Salk could protect only against paralysis, whereas Sabin's live attenuated vaccine could guard against both paralysis and infection. Dr. Sabin demonstrated the effectiveness of his vaccine in the field trials during the period 1958 and 1959. After a clash between the rival camps and their principals, by 1962 Salk's vaccine was replaced by the Sabin vaccine<sup>22</sup>.



*Albert Bruce Sabin improved upon the Salk vaccine and developed a live attenuated oral Polio.*

Sabin's, live oral polio vaccine (OPV) for immunization against poliomyelitis, vaccine could be taken orally and it provided longer immunity than the killed-virus vaccine. This vaccine became available for use in 1963. The Sabin oral vaccine is given in 3 doses in the first two years of life, and a booster is given subsequently when the child starts his schooling. Further boosters are not given unless the patient is exposed to polio or travels to an endemic region. The advantages of a live, oral vaccine are its long-lasting immunity, the prevention of re-infection of the digestive tract, and the lower cost of administering the vaccine orally because sterile syringes and needles are not necessary. Sabin's oral polio vaccines are used in India during the National Immunizations Day campaigns.



*Sabin's Oral trivalent polio vaccines that are routinely used in Pulse Polio Campaigns in India.*

## Progress towards eradication of polio

The eradication of the polio with the use of Polio vaccines in the developed nations prompted the World Health Organization, in 1988, to set a goal for itself of eradication of poliomyelitis from the entire world by the year 2000<sup>23</sup>. Although way off the target the world is now poised for this unprecedented achievement. The results speak for themselves. The number of polio cases worldwide has been cut dramatically in just over a decade. In 1988, according to WHO, there were an estimated 350,000 cases<sup>24</sup>, of which only 10 per cent were actually reported. Unfortunately the goal of polio eradication by the year 2000 could not be achieved. All but 6 countries - India, Pakistan, Egypt, Afghanistan, Nigeria and Niger, achieved elimination of WPVs by 2000.

By the end of 2001, the number of cases had dropped to 537. Although the number of reported cases increased during 2002, due to polio outbreaks in India and Nigeria, the majority of these cases were concentrated in isolated areas thus giving an optimistic view for a world free of polio<sup>25</sup>.

### Polio Eradication Efforts in India

India officially committed itself to eradicate polio, supporting the WHO resolution to that effect in the very same year 1988. India had more polio cases than any other country in the world. It was estimated that the Indian health care personnel officially reported to the government over 24,000 cases of polio<sup>26</sup> in reality though, there were probably many more cases that went unreported. The sight of children and adults with withered arms and legs throughout the cities, towns and villages of India was routine, and some of the major risk factors for polio virus transmission like crowding, poverty and poor sanitation were present in India to a degree not seen in most countries.

India was slow to adopt the campaign of polio eradication. Some officials were skeptical of its implementation and argued that there were other more pressing health priorities in India and that the cost of polio eradication campaign would limit resources for providing health services to India's general population. However, India was able to commit to the programme largely due to the influence of Dr. John Andrus, an American from the US Public Health Services who arrived in India in 1993 as Regional Adviser for polio on the WHO/ SEARO (South East Asia Regional Office) staff and Dr. Kaushik Banerjee, Director of India National Immunisation Programme in the Ministry of Family Welfare.

National Immunisation Days have been a common feature of the Indian Polio eradication programme for quite some time now. Each year more than 170 million children, under the age 5, are vaccinated on these days and nearly a billion doses of oral polio vaccines are administered annually. Indian polio eradication campaign, which was an epidemiologic challenge of unprecedented proportion, tells an inspiring story. If the milestone of eradicating India endures, which it most likely will in the next two years, it will be the result of a persistent and focused effort and unprecedented collaboration among scientists, administrators and international collaborators. This campaign has

combined cutting edge research on vaccines and door to door follows up, public and private outreach, political desire and relentless surveillance.

Polio eradication programme in India is spear headed by the government of India, along with key partners WHO, UNICEF and Rotary International. The initial combat on polio came with the introduction of universal immunization programme in 1985. Under the Universal Immunization Programme (UIP), more Indian children were provided oral polio vaccine (OPV) than ever before in history.

This campaign now involves more than 2 million volunteers besides the Indian chapters of Rotary International. It reached 87 million children during the National Immunization Days in 1995 & 1996 and in the very next year it reached 125 million.

The number of reported polio cases dropped from over 24,000 in 1988-89 to less than 5,000 in 1993-94. Although this was encouraging, the government of India soon responded to the need to intensify the polio eradication effort and accordingly developed the Pulse Polio Immunization (PPI) strategy. The key innovation in this programme was utilization of mass immunization campaigns to supplement the routine immunization activities. The state of Delhi was the first area to adopt a PPI component in 1994. The first round of National Immunization Day (NID) programme was held in late 1995, which was followed with a second round in early 1996. Children under the age of 5 years were invited to take polio drops. Over 500,000 booths were set up nationally during the first NID programme, and on a single day a total of 87 million children received the vaccine. The scope and intensity of mobilization utilized for this activity has been unprecedented in the annals of the health initiatives in India, and possibly, the world.



*Children celebrating one complete year of Polio free India.*

To understand this remarkable achievement, it is important to comprehend the scale of the efforts made to meet this gigantic challenge. At the same time as the NIDs were being initiated, it became clear to the government that better information on polio cases was necessary to complete the job of polio eradication. The government of India and the WHO developed a collaborative unit, the National Polio Surveillance Project (NPSP)<sup>27</sup> to provide accurate and rapid surveillance information on polio cases in India. There is now a systematic tracking of cases finding the source of the infection and flooding infected area with massive doses of polio vaccines. Beginning in 1997, NPSP has supported over 300 surveillance medical officers throughout India to coordinate polio surveillance activities. In addition to NPSP network, a regional laboratory network of 9 highly qualified Indian research centres provides rapid and accurate analysis of samples from patients.



*Polio vaccination in a train.*

Polio cases came down to 265 in the year 2000 and in the backward state of Orissa it came down from 45 to Nil. In the year 2002 polio bounced back and 1600 cases were reported. The number of cases of polio in the year 2005 was 66 and during the years 2006 to 2009 they ranged from 550 to 874. Once again the year 2010 was very effective and polio cases came down to just 43 cases. Last recorded case of wild polio virus infection was in Jan 2011.

The major players in the global polio eradication initiative (GPEI) include the WHO, CDC, UNICEF and Rotary International and private donors like the Gates Foundation. India accounts for 32% of financial requirements for the GPEI. India has financed a

cumulative total of 1 Billion US \$ for polio eradication between 2003 and 2010<sup>28</sup>. India will be spending 79% of the campaign cost between 2011 and 2013. International funding has supported social mobilization. Gates Foundation is the largest donor and other agencies include WHO, UNICEF, DANIDA and Rotary International.

The success story of Indian polio eradication programme and the vigilance that we should continue to keep on the wild polio virus can best be summed up in the words of the Union Health Minister, Shri Ghulam Nabi Azad, who, while announcing the completion of one full polio free year on 13 Jan 2012, said "We are excited and hopeful, at the same time, vigilant and alert" and cautioned, "there is still no room for complacency and we need to ensure no case of polio infection for three consecutive years for India to celebrate eradication of poliomyelitis".



*Polio vaccination in rural India.*

## Conclusion

Heading towards the third consecutive year of freedom from wild polio, India has developed an end game strategy for ensuring a polio free world with support from WHO and other partners. It has taken a carefully planned strategy of a phased withdrawal of the oral polio vaccines from the mass immunization programmes and phasing in the use of inactivated polio vaccine (IPV) to complete the eradication process and containment of all wild, vaccine-related and Sabin polioviruses. It is also necessary for India to guard against the risk of polio resurgence through a distant or cross-border importation of the wild poliovirus especially from our neighboring countries like Pakistan

and Afghanistan, where the virus continues to circulate. The experience gained from this project and the polio infrastructure and expertise developed in the process will be immensely beneficial in strengthening the routine immunization programmes in India for protecting our children from various vaccine - preventable diseases, as well as for overall strengthening of the existing public health systems by applying the lessons learnt during the course of polio eradication.

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## The Ganga Gallery : Science Exhibition on a Socio-Cultural Theme

**Samarendra Kumar**

### Background

*"The Ganga, especially, is the river of India, beloved of her people, round which are intertwined her memories, her hopes and fears, her songs of triumph, her victories and her defeats. She has been a symbol of India's age-long culture and civilization, ever changing, ever flowing, and yet ever the same Ganga".*

These words and sentiments expressed by Pandit Jawaharlal Nehru, the first Prime Minister of India, in his book 'The Discovery of India' truly reflect the position of the river Ganga in the Indian socio-cultural landscape. From ancient times to the present day, the story of the river from her source to the sea subsumes the story of India's culture & civilization, of the rise and fall of great empires and proud cities, and of human adventures. No other river in the world is possibly so intimately identified with a country and its culture as the Ganga is for India. It is the life-line, a symbol of purity and virtue for millions of people living on its bank and on the land it flows through, representing their ethos, socio-economic culture and techno-scientific practices.

From time immemorial, people of all hues have resorted to the river for purifying their body and soul, for quenching their thirst and that of their crop-producing soil, for performing very many religious rituals, for transportation, and verily for every conceivable function of life. Revering Ganga like a mother deity, succeeding generations have called upon her to make one's day blissful by providing fresh and life giving water. The river occupies a unique position in the cultural ethos of India. Legend says that the river descended from the heavens as a result of the long and arduous prayers of King Bhagirath for the salvation (Moksha) of his deceased ancestors.

Sadly, now the great life-giving river itself, along with the unique ecosystem she nurtured over the entire basin, is severely challenged for survival with her dirty, polluted and scanty remains.

This story of the Ganges, from its glorious days to the modern times, needed to be told once again in order to re-emphasize her importance for India and to sensitize

people towards taking appropriate steps for revival of her past glory.

### Project Initiation

With this in view, the National Academy of Sciences, India (NASI), the oldest Science Academy of the country located in Allahabad, decided in 2010 to set up a gallery on Ganga at Allahabad. The idea was mooted by Prof. MGK Menon, Prof. M.S.Swaminathan and Dr.(Mrs) Manju Sharma (Past Presidents of NASI) for creating awareness among the masses for the preservation and conservation of Ganga.



*DG, NCSM addressing during the Inaugural Programme.*

NASI initially approached Regional Science City, Lucknow and National Science Centre, Delhi Units of NCSM for setting up this gallery at Allahabad and in May 2010 an MOU was signed between NCSM and NASI for setting up the gallery. After finalizing the concept plan in a series of consultations with NASI, it took about eight months of rigorous work for completing the project. The gallery was finally inaugurated on April 15th 2011 by the then Union Science and Technology Minister, Shri Pawan Kumar Bansal.

The project was coordinated by Regional Science City, Lucknow and a unit of the National Council of Science Museums.

### Conceptual and Design Challenges

The making of the gallery on the river Ganges with its

socio-cultural and economic significance was a challenging proposition. While on one hand it was necessary to weave a story keeping in mind popular beliefs and sensitivities, portrayal of real issues plaguing the great river's survival today. Also, it was absolutely necessary to tell this story using appropriate media suitable for all classes of visitor's including the experts, the laymen and the faithful.

Thus after a careful consideration of all related aspects of the gallery, an initial concept plan was submitted to NASI covering a total exhibition area of about 3500 sq. ft.. Thereafter, several rounds of discussion and review followed before the final list of exhibits and gallery plan was finalized.

The design of the gallery had to be appropriate to suit the socio-cultural fabric of the storyline. The introduction was done by depicting Ganga as the mother and life-giver to millions of people using an aesthetically crafted idol and diorama.

Since the gallery spread over two floors, the entire exhibition had to be very carefully laid out. It was decided to divide the exhibition into two parts. The exhibition space on the first floor was used to display the exhibits on mythology, landscape, socio-cultural aspect of Ganga, biodiversity of the gangetic basin and the economic influence of the river.



*3D AutoCAD plan of the gallery.*

The space on the second floor was devoted to portray the current state of affairs of the river from a scientific viewpoint, which include the principal causes of pollution of the holy 'Gangajal', impact on life systems that it supports, issues related to climate change and its implications for the health of the river, and the various other factors affecting the Ganga. Lastly, the exhibition talks about the efforts that are needed to save the river

and about what is being currently done in this regard.

### **Use of Technology**

Because the gallery had to deal with a culturally sensitive scientific issue, it had to be socially appropriate, visually appealing and scientifically correct, while at the same time being very user friendly. This required innovative use of technology for ensuring easy access to information and interpretation services for the visitors.

Touch screen multimedia, RFID supported interactivity with exhibit contents and interactive dioramas and many other technology-based presentation techniques have been used in the gallery to make it easy and exciting to operate as well as engagingly informative.



*Use of RFID sensors in exhibits.*

### **The Gallery**

On entering the gallery, a Ganga hymn welcomes the visitor and sets the mood for a memorable experience about the river. The myths connected with the river are portrayed by appropriately designed dioramas and supplemented by multimedia presentations. The river Ganga has held India's heart captive and drawn uncounted millions to her banks since the dawn of history. The beliefs and myths associated with the river are presented in the form of a multimedia to help people explore more about them from a cultural perspective.

The source of the river Ganga is a topic of research in itself. A systematic attempt has been made to tell the story of the search of the source in the gallery. Historically, several attempts were made to search for the source of the river. Prior to 10th century, European geographers and cartographers tried to locate the source of the River Ganga on their maps. Jesuit missionaries traveled facing all odds to the lake Mansarovar in the early 17th century and brought back the legend that it was the source of Ganga. Chinese Cartographers too who went to Tibet told the same story. In 1733, it received official recognition after it was published, as part of a four volume description, de l' Empire de la chine and later in James Rennels "Memoir of a Map of Hindustan" in 1783. In 1808, East India Company sent Captain Webb to survey the Ganges from Haridwar to Gangotri (Gaumukh or the Cow's mouth). They gathered reliable information that the source of river is more remote than the place called Gangotri. James Ballie Fraser was the first European to actually reach Gangotri in 1815, followed by Captain J. A. Hodgson two years later, who continued his journey upto Gaumukh and officially discovered the source of Ganga.

The opening of the Ganges in the mountainous gorge at the foot of the Himalayas in Haridwar is also known as Gangadvara. Gangotri is the place from where the Ganges descends. One of the longest glaciers of India, Gangotri glacier's snout descends steeply down 7138 metres from the northwest slopes of Chaukhambha peaks. Bhagirathi, one of the tributaries of the Ganga, originates from the Gaumukh snout of Gangotri glacier, whereas the Alaknanda, the other main tributary emerges from the Bhagirathi Khark and Satopanth glaciers, east of Chaukhambha peaks. After flowing in opposite directions from their respective snouts they meet at Deoprayag and henceforth collectively known as Ganga.

An interactive diorama takes the visitors on a journey to the origin of the Ganges providing scientific information on the glacial ice that feeds the river and associated issues. A specially designed ice-making unit with an opening to let the visitor touch and feel the ice represent the source of the river Ganges.



*Ice formation unit installed in one of the exhibit.*

## Tributaries of Ganga

The interactive exhibit on *Tributaries of Ganga* makes the visitors explore the various tributaries of the river- their sources, travel paths and lengths. It has many tributaries, both in the Himalayan region before it enters the plains at Haridwar and further downstream before its confluence with the Bay of Bengal. The important tributaries and sub - tributaries of Ganga are: Yamuna, Ramganga, Gomti, Gharghara, Gandak, Kosi, Kali / Sharda, Chambal, Sindh, Betwa, Ken, Tons, Sone, Punpun, Damodar & Kangsbatī Haldi. According to Hindu mythology there were about thirty six tributaries of Ganga, some of which are not traceable now.

## The Voyage of Ganga

The Voyage of Ganga is an extraordinary journey from the mountains to the ocean. Originating from the Gaumukh in the Himalayas, the river flows through the Sivalik hills and enters the plains at Haridwar. From Haridwar, it flows southwards, meandering over several hundred kilometers in the Indo-Gangetic plains in Uttar Pradesh, Bihar and West Bengal before ultimately joining the Bay of Bengal. Ganga's total path is about 2,525 km long and its basin is spread over approximately 8, 61,404 square km area, which drains almost one fourth of the country. This *voyage of Ganga* is

experienced by the visitors through an interactive multimedia and a visual-seeker technology especially developed for the exhibit.



*Prof. MGK Menon interacting with an exhibit.*

The water of river - 'Gangajal' - is considered to be sacred and having pristine properties. In Hindu rituals and "Sanskaras", the Gangajal is very important. For example in the Mundan sanskara, a young child is shaven clean with Gangajal; because the water was believed to be so pure in the ancient time that washing the head just after using the razor, was enough to wash out the germs.



*Ganga water from past to present.*

Scientific reasoning for this ritual has been depicted in the gallery. It has been found that the Gangajal has extraordinary self-purifying abilities because of its high content of dissolved oxygen (DO), extraordinary high rate of re-aeration, long DO-retention abilities, fast assimilation of the putrefiable organic matter, presence of sulphur & radioactive traces, naturally occurring

extracts of medicinal herbs, low temperature gradient at the origin, high flux density & flow, presence of beneficial algal and diatom population, abundance of predatory fauna besides the long duration of sunshine along the Gangetic region has always had its impact (electro-magnetic radiations) on microbial population. Possibly because of these properties, Gangajal had its intrinsic value in Hindu Sanskaras from ages.

### **Gangajal**

The people of India revered and worshipped Ganga due to its purity and extra self-purifying properties and hence the river featured prominently in Indian classics and folklore. The descent of Ganga from heaven to earth has been glorified in great works of Indian art and literature. Many popular movies in India revolve around the mystique of the river, so are many popular songs.

### **Shaping the Socio-economic & Cultural Landscape**

The Ganga basin was so fertile that people living around it could cultivate a variety of crops and with every harvest they used to offer a share to Ganga on whom they were dependent for their livelihood. Gradually these became the mark of their rituals taking shape in many celebrations, pujas, purvas and festivals. The main festivals about and around Ganga are: Kumbh Mela, Sawan Mela, Magha Mela, Kartik Poornima, Ganga Dusshera, Chhath Puja and Ganga Sagar Mela.

The nearby cities along the river Ganga grew into trade centres as navigation along the Ganga was the main source of transportation in ancient India giving rise to interaction and fusion of different trades and cultures such as Varanasi, Paan & Thandai, Madhubani Art & Murshidabad Painting etc. The evolution of sacred complexes along the river Ganga also gave rise to universalization of traditions and made the rich art of this region popular. Some of these are Shehnai, Akharas and Ganga Arti. The fusion of trade, culture and complexes made the priesthood holy and a famous occupation that flourished in several other religious practices and making it a part of our great tradition. Ganga Arti is a special ritual performed at many places on the banks of Ganga on special occasions in which thousands of people participate for worshipping the mother Ganga, their lifeline.



*A view of the 2nd floor of the gallery.*

An aesthetically designed TV studio set-up in the gallery allows visitors to become a part of the 'Ganga Arti' celebrations at different places and also to take a printout of his photograph virtually standing near the Gomukh, Lakshman Jhula, Varanasi Ghat or Allahabad Sangam. This is one of the most attractive exhibits of the gallery.

Apart from its cultural significance, the river Ganga is the source of livelihood to more than 450 million people living in its basin who are directly or indirectly dependent on the river. The river and its tributaries have supported diverse occupations for the people in areas such as agriculture, power generation, fisheries, transport & tourism, poultry & live-stock farming, pottery, sand-mining, art & craft, several small, medium and large scale industries.

## Tourism

The cultural importance of Ganga has also led to development of the tourism industry across the length & breadth of the river. Religious heritage cruising, wildlife cruises featuring with access to a number of national parks, white water rafting, Ganga rallies, floating restaurants etc. are some of the tourism activities that are regularly conducted in and around the river Ganga.

## Inland Water Transport

In ancient times the Ganges and some of its tributaries, especially in the east, were important transportation routes. According to the ancient Greek historian

Megasthenes, the Ganges and its main tributaries were being navigated in the 4th century BC. In the 14th century, inland-river navigation in the Ganges basin was still flourishing. By the 19th century, irrigation-cum-navigation canals formed the main arteries of the water-transport system. The advent of paddle steamers revolutionized inland transport and thereby stimulated the growth of indigo production in Bihar and Bengal. Regular steamer services ran from Kolkata up the Ganges to Allahabad and far beyond, as well as to Agra on the Yamuna and up the Brahmaputra River.

Considering the advantages of Inland waterways for movement of bulk cargos like coal, cement, fly ash, food grains and fertilizers, the 1620 km stretch of Ganga between Allahabad & Haldia has been declared as National Waterway I.

The gallery has a RFID sensor-based exhibit that lets the visitors explore about some of the important occupations directly connected with the Ganges. In addition, specially made video films shot at locations like Allahabad, Kanpur, Patna, Haridwar highlights the importance of the Ganga in India's socio-cultural and economic landscape.



*A view of the Gangetic ecosystem section of the gallery.*

## Ecosystems

The Gangetic ecosystem sustains a diverse flora & fauna, which not only help maintain the pristine purity of water, but also serve as a resource for humankind. The river at present nurtures over 140 fish species, 90 amphibian species and five avian zones. The basin is

home for the endangered Ganges dolphin, a rare freshwater shark variety *glyphis gangeticus* besides several species of microorganisms.

However, the Gangetic dolphins today face a number of threats for its survival due to a wide range of human induced disturbances like modification of river flows, change in nutrient and sediment fluxes, water pollution from urbanization, use of chemical fertilizers and pesticides for farming in the river corridor, agriculture, overexploitation of fish resources and poaching of dolphins for oil and meat. Vikramshila Gangetic Dolphin Sanctuary (VGDS), a highly productive 65-km stretch of the lower Ganga River between Sultanganj and Kahalgaon in Bihar, is the only protected area specifically created for saving this endangered river dolphins in India.



*Diorama of Sunderbans.*

The story of the Gangetic biodiversity would be incomplete without the mention of the Sunderbans, a pristine mangrove swamp at the southern fringe of West Bengal covering 102 islands in the emerald estuarine waters of the tributaries of the Ganga and the Bay of Bengal. The home of the famous Royal Bengal Tiger and one of the largest deltaic ecosystems in the world, importance of Sunderbans is underwritten by the fact that it is in the list of World Natural Heritage Sites (1985) and also is a Biosphere Reserve. The gallery has a specially designed diorama on the Sunderbans with an animated Royal Bengal Tiger. A sensor based switching device coupled with a hydraulic system has been used for making the Tiger model look real-life like.

### Science of 'Gangajal'

The second floor of the gallery is devoted to scientific aspects of the river Ganges and its water. For example the physico-chemical and biological properties of water such as Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), pH, temperature, acidity, alkalinity, turbidity, hardness and coliform count have been explained using an interactive multimedia. One can also learn about the permissible limits for each one of these parameters, which are regularly monitored by the central and state pollution control boards.

The multimedia presentation also explains why 'Gangajal' which has been revered through ages because of its unique properties. While flowing through the Himalayan region over different types of rocks, a number of chemical substances get dissolved into the Ganga water. During runoff from its catchment area, the river's water carries many medicinal plants found abundantly in this region which add alkaloid and other useful chemical substances to its water. Ganges water does not putrefy, even after long periods of storage.

The uniqueness of the Ganges water captivated the imagination of people across caste, religion and geographical boundaries. Historical facts and anecdotes have been presented to elaborate these aspects in the gallery. Mughal emperor Akbar's preference for 'the water of immortality' from Ganga for drinking and cooking is described at length in the *Ain-i-Akbari* by Abul Fazl. Bin Tughluq in the year after 1327 carried the Gangajal braving a forty day long journey for his own personal use when he established the new capital of Delhi Sultanate in Daulatabad. British physician, C.E. Nelson observed that Gangajal taken from Hooghly by ships returning to England remained fresh & sweet throughout the voyage. It is also reported that *Bdellovibrio*, a genus of Gram-negative obligate aerobic bacteria, is found in Ganga water which kills bacterial species responsible for decomposing the organic matters present in the water. Ernest Hankin, a British bacteriologist, reported in 1896 on the presence of marked antibacterial activity against *Vibrio cholera* and D'Herelle called it *bacteriophage*. Thus in a way the world owes the discovery of bacteriophages to the Ganges water. In 1896, the

British physician E Hanbury Hankin, reported in the French journal *Annales de l'Institut Pasteur* that cholera microbes died within three hours in Ganga water. A French scientist, Monsieur Herelle, was amazed to find that a sample of the river's water drawn from only a few feet below a floating dead body of a person who had died of dysentery and cholera contained no germs of the disease.

## Threats

The watershed of the river Ganga spreads over ten States of India, namely Uttaranchal, Uttar Pradesh, Bihar, Jharkhand, West Bengal, Himachal Pradesh, Rajasthan, Haryana, Madhya Pradesh and Delhi covering 26.2 percent area of India's total geographical area. However, during the past few decades, water of the river has started losing its age-old charm and efficacy due to discharge of huge quantities of untreated city sewage and toxic industrial effluents. The other major reasons for the river's degradation are cremation of dead bodies, agricultural runoff, solid and bio-medical waste disposal, animal bathing, washing of clothes, disposal of temple ritual wastes, extraction of water through lift canals, deforestation in water shade areas, construction of dams in the Himalayan region and large scale urbanization along the river. A multimedia supported with a video film make the visitors ponder over the major threats the holy river is facing today. A diorama of a Sewage Treatment Plant and the supporting multimedia make the visitors understand the process of sewage treatment and how it can be effectively used for saving the Ganga and other rivers.

The environmentally sensitive Indo-Gangetic plain (IGP) is also severely threatened by climate change. The major concerns are fluctuations in precipitation levels and seasonal distribution of river flows, drying up of aquifers, flooding and submergence of low-lying areas including glacial lake outburst flood (GLOF), increase in river bed sedimentation, salt water invasion in freshwater systems, soil salinization etc.

Another important issue is about the dams along the river. The Ganga along with its tributaries and distributaries support a massive network of irrigation channels and a number of hydroelectric projects. The construction of large dams heavily alter the natural

flow of the river affecting every aspect of a river ecosystem including water quality, sediment transport and deposition, fish migrations, riparian and floodplain habitat. The presentations in the gallery open up the question whether the Big Dams are necessary for India. While there are six primary threats faced by the endangered river basins in the world, namely, over-extraction of water, dams & infrastructure, invasive species, climate change, over fishing and pollution, the Gangetic basin suffers most from over-withdrawal of river water and rampant pollution. And both of these are direct consequences of anthropogenic pressures. The Human impact may rob the pristine river its glory and sacredness.



*Senior Fellows of NASI interacting with the exhibits.*

A collective action from all the stakeholders- the people and the state - is needed to bring Ganga to its original glory. A section of the gallery has been especially devoted to various government initiatives like setting the Ganga Action Plan (GAP) and establishing the National Ganga River Basin Authority (NGRBA) over the years in order to restore the river. The NGRBA is a planning, financing, monitoring and coordinating body for effective abatement of pollution and conservation of the river Ganga in keeping with sustainable development needs.

The gallery ends with the exhibit Ganga Pledge where visitors where visitors can input their pledge for putting life back into the holi Ganga.

## Feedback

The gallery since its opening in 2011 has been well received by scientists, scholars, students and common

people. Regular surveys are conducted by NASI to get visitors' feedback of the gallery. The gallery finds a place in the tourist map of Allahabad. That a prototype of the Ganga exhibit was on display at the recently concluded Kumbh Mela for viewing by millions of pilgrims is a testimony that the Ganga gallery has been able to catch public fancy and imaginations.



*Dignitaries taking the Ganga Pledge in the gallery.*

### Conclusion

Handling a crucial socio-cultural theme as sensitive as the River Ganga, treating it from a scientific viewpoint and making an exhibition gallery was a challenging task. One had to be extra cautious not only about the scientific facts and figures but also about dealing with the socio-cultural and religious sensitivity connected with the theme. As the intended target visitors were people from all strata of the society, design of exhibits and presentations had to be commensurate over a range of intellectual and cultural profile. Ease of exhibit operation, interactivity and interpretation demanded careful choice of technology and innovative display techniques. Effective use of dioramas, hands-on interactive exhibits, colourful illustrations/visuals, animations, digital interfaces, multimedia programs and video based presentations made the gallery an enjoyable and learning experience for one and all.

### Acknowledgement

Author is grateful to Prof MGK Menon, Prof (Mrs.) Manju Sharma, Prof. M. S. Swaminathan, Prof Asis Datta, Prof. A.K. Sharma and other senior fellows and all the learned members of the NASI-Council of NASI, for inspiration, guidance and valuable inputs in shaping of the gallery. He is also thankful to Prof Krishna Misra, General Secretary (HQ), NASI, Dr. Neeraj Kumar, Exe. Secy., NASI & other officials of NASI,

Prof. V.D. Tripathi of BHU, Prof Vinod Tare of IIT, Kanpur, who have given him their valuable advices and regular support. His special thanks are due to Shri G.S. Rautela DG, NCSM and the team of museum professionals at NSC, Delhi and RSC, Lucknow for the creative visualization and making of the gallery.

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## Portrayal of the Present State of Biomedical Science and Technology at Regional Science Centre, Jaipur

*N Ramdas Iyer*

### Abstract

The rationale behind the development of the concept for the Biomedical Revolution Gallery at the Regional Science Centre, Jaipur, Rajasthan, India, rests on two fundamental concepts. One, that the progress of medicine from what it was in prehistoric times, to what it is today, was not a continuum of inventions and discoveries, each supplementing and adding to the existing corpus of knowledge but was a series of bursts, sometimes totally unrelated to the existing knowledge in the field and two, it borrowed heavily from fields far diverse and those that have no direct bearing whatsoever with the fundamental foundations of medicine, biology and chemistry. These two concepts recur repeatedly and are emphasised at regular intervals in the Gallery. Besides, the extensive use of vivid three dimensional visual components like period settings and dioramas supported by technology makes the Gallery very visual and emphatic.

### Biomedical Revolution as a Revolution

It is essential to understand the nature of a revolution. Thomas Kuhn, in his classic "The Structure of Revolutions" mentions that "Scientific revolutions are inaugurated by a growing sense, ....often restricted to a narrow subdivision of the scientific community, that an existing paradigm has ceased to function adequately in the exploration of an aspect of Nature to which that paradigm itself had previously led the way.....and the sense of malfunction leads to a crisis that is a prerequisite to the revolution". A slight elaboration is in order here, and I do that using the example of the Copernican revolution or the Einsteinian revolution. The Ptolemaic astronomy and Aristotelian astronomical principles were considered entirely adequate to explain and indeed understand the corpus of astronomical knowledge as it existed till Galileo came up with certain startling observations that the existing paradigms entirely failed to address. Similarly, Newtonian mechanics was comfortably placed to explain all observed mechanical phenomena entirely till certain observations made by Michelson and Morley

rendered it insufficient. An entirely new mechanics had to be formulated. Similarly, several biomedical concepts had to look for newer paradigms to explain certain new and startling observations from the 17<sup>th</sup> Century to the 20<sup>th</sup> Century to explain them. As an example I quote the fact that, though it was known that the heart pumps blood through the body, the facts that the volume of blood in the body was limited, and that the heart seems to pumping a lot of excess blood during a lifetime, brought the understanding of the mechanics of flow of blood through the body to a standstill till the advent of the microscope made the visualisation of capillaries possible and Harvey correctly surmised that the it was the same blood that circulated throughout the body time and again. This required a totally and radically different understanding of the mechanics of blood circulation and also new instruments and techniques borrowed from an entirely different field of science – optics- in the form of a microscope, to grasp. There are several such milestones in biomedical technology, which exhibit a paradigm shift from one school of thought to a new one, and these are the milestones that the gallery attempts to portray as a story. This story is told using certain landmark exhibits - by landmark, I mean exhibits, which portray these paradigm shifts interspersed with explanatory and supplementary exhibits to tell the story in detail. I will attempt to explain each of these in a little detail<sup>2</sup>.



*Rhinoplasty in ancient India.*

Medicine has naturally had a long tradition in ancient civilisations, including India. Surgery was performed but it was a last resort. The methods employed by surgeons were not very refined and therefore, medication was the first choice. A break from tradition occurred with Sushruta (circa 600 BC)<sup>3</sup>. Sushruta was no doubt a skilled surgeon, but even his surgeries were not much sought after by ordinary patients. It was a particular necessity among certain members of the society that spurred rhinoplasty and refined it to a fine art in ancient India. Criminals in ancient India had to endure a punishment, which involved cutting off the nose of the criminal. This procedure finds reflection even in present day usage in several Indian languages in the form of an idiom “Naak katwana”, meaning “cutting off the nose” to indicate a shameful act. The rationale behind this punishment was manifold. First, a person may lose his limbs or even head by means like accidents, wars etc. and losing a nose, while keeping the face intact, is not at all common. Hence, absence of a nose certainly signified an induced loss. Second, the nose being a prominent feature of the face – the most visible and viewed feature of a human being, is most liable to be missed on observation and therefore this punishment certainly served the purpose of branding criminals. One might justifiably hide any other part of the body without raising undue suspicions, but not the nose. Third, loss of nose did not often seriously impair the quality of biological life of the person, though it might seriously affect other aspects of his life – social and psychological. It could therefore be deemed a relatively humane mode of punishment while certainly introducing a marker indicating delinquency. This is good enough for the society, but it was not a happy situation for the criminal. Criminals therefore sought a means to get the cut nose reasonably reconstructed so that they could lead a relatively normal life. Further, even in the absence of anaesthesia, criminals who were desperate to get back into the mainstream, were willing to endure some pain involved in surgery. Sushruta used these circumstances to develop rhinoplasty – reconstruction of the nose – to perfection, and is therefore justifiably hailed as the father of modern reconstructive surgery<sup>4</sup>. Reconstructive surgery, which otherwise would not have even contemplated arose therefore, out of a societal necessity and was extended to other parts of the body like correction of mutilated ear lobe defects and techniques for repair of torn ear

lobes, cheek flap for reconstruction of absent ear lobe, repair of accidental lip injuries and congenital cleft lip, piercing children's ear lobes etc. This is elaborated in the period setting “Surgical Traditions of Ancient India”<sup>5</sup>.

## Advancements in Anatomy and Physiology

Moving on to modern times, medicine was for long hampered by the fact that the interior of a human body was a mystery. The fact that it was taboo to cut open even a dead human body and there were religious injunctions against it, prevented humankind from really knowing the anatomy and physiology of a human body. It was when Andreas Vesalius in 1543 defied social and religious norms to dissect human bodies, and based on his observations, published his great anatomical treatise, that the knowledge of anatomy took off. The illustrations by an unknown artist set a new standard for the understanding of human anatomy<sup>6</sup>. Similarly, in physiology in the 17<sup>th</sup> century, William Harvey established that the blood circulates within a closed system with the heart serving as a pump. This understanding provided an impetus that could not have been possible using the earlier corpus of knowledge and is explained in the exhibit “Past and Present – A study in contrast”.



*An exhibit depicting the contrast between past and present practices in medicine.*

## Cell Biology

Today every high school student learns that cells are the

understanding did not exist till the recent past. In the 17<sup>th</sup> century, Anton von Leeuwenhoek<sup>7</sup>, with an object held close to the lens he had made, was first able to see minute "animalcules" and discover that tissues had complex inner structures. Others like Robert Hooke, Matthias Schleiden and Theodor Schwann, and Rudolf Virchow, Ludwig Aschoff, and Carl Rokitansky developed further insights. Proceeding to sub cellular biology, in the 20<sup>th</sup> century, Ernst Ruska made the first electron microscope in the early 1930s. With this primitive apparatus and, later, more sophisticated machines, the rich subcellular structure became visible. With these developments, several heretofore unknown facts like fertilizations and the detailed mechanism of sexual reproduction, embryology, and even cancer became possible to be understood, since these involve the cellular structure<sup>8,9</sup>. This is shown in the exhibit on "Microscopy" in the Gallery.

### Anaesthesia

Humans have been operating upon one another since the Stone Age but before the invention of effective pain-killers, surgery remained an agonising last resort. Patients were held or strapped down and many died of shock on the table. Doctors relied on speed, not accuracy, so surgery was a hit-and-miss affair - as few as 50 per cent of patients survived. Those who did certainly did not enjoy the experience. Despite ongoing and often desperate efforts to dull the pain - from opium and alcohol to throttling patients to stupefy them or even freezing limbs prior to amputation. Nothing really worked until the discovery that inhaling certain gases induced blissful unconsciousness. And thus was anaesthesia born<sup>10</sup>.

Humphry Davy was first to realise the pain-killing effects of nitrous oxide (laughing gas), originally used as a party drug in "frolics". By the 1840s, it was being used to ease dental extractions, but its effects were too short-lived for more major surgery. That had to wait for the discovery of ether, a stronger anaesthetic also popular as a party drug that was first used in surgery by William Thomas Green Morton at Boston's Massachusetts General Hospital in 1846<sup>11</sup>. The following year, Edinburgh gynaecologist Sir James Young Simpson pioneered the use of chloroform, simultaneously discovered by three independent researchers in 1831, to ease the pain of childbirth. Interestingly, it was till then

believed that women were fated to endure its agonies as a punishment for original sin. Anaesthesia also therefore, in a way, worked towards eliminating stereotypes against women. This is portrayed in the exhibit on Anaesthesia.

### Asepsis and Antisepsis

Infection control remained problematic so long as its causes remained unknown and infections were routinely ascribed to the action of evil spirits and later to "miasma" (bad air). The real culprits - bacteria - were first spotted in 1683 by Dutch merchant Anthony van Leeuwenhoek, inventor of the microscope, who described the "animalcules" (tiny animals) he saw swarming in his own saliva. By 1847, Hungarian doctor Ignaz Semmelweis had noticed that women delivered by midwives were much less likely to die of childbed (puerperal) fever than those delivered by medical students fresh from the dissecting rooms. Semmelweis deduced that "putrid particles" were somehow being transferred from the corpses they had been cutting up to the new mothers' wombs and ordered the students to wash their hands in lime chloride. Cases of childbed fever dropped, but Semmelweis's theories were not widely accepted until after his death.

"Hospitalism", as the diseases septicemia, erysipelas, and pyemia began to collectively be known was the root of the overwhelming mortality rate in the hospital setting. Joseph Lister, Regius Professor at the university in Glasgow was aware of this, and he studied the works of other prominent scientists to learn that the infections were not caused by a chemical reaction, or an oxidation, that occurred when oxygen touched the wound, but by tiny organisms from the air.

The problem that vexed Lister the most was that of sepsis following compound fractures, a fracture in which the skin is broken and the bone exposed. Such a malady required surgery and had an extremely high mortality rate, especially when the individual remained in the hospital following the surgery. After learning of Louis Pasteur's work and doing his own experiments, Lister knew that he needed to keep the wound free of the microbes that were causing the infections. Joseph Lister had heard of Carbolic Acid being used to remove the odours from sewage and decided to try to use it on a small boy with a compound fracture of his leg.



*Sepsis and Antisepsis - Joseph Lister's work.*

The wound did not suppurate following surgery and the only injury was that the acid was burning the boy's skin. Lister explained the case and the following ones in which he perfects his method in his essay "On a New Method of Treating Compound Fracture, Abscess, etc.". Lister also discussed his removal of abscesses, a surgery considered an unnecessary risk during those days. Lister's survival rate was astonishing and other surgeons and professionals began to pay notice<sup>12</sup>. Gendler disinfectants and surgical rubber gloves were introduced; instruments, ligatures and wound dressings were sterilised, and post-operative mortality rates plunged.

Meanwhile, Louis Pasteur<sup>13</sup> was busy propagating the germ theory - that microscopic airborne organisms invading the body were responsible for infections. Asepsis, coupled with the developments in anaesthesia, meant that riskier operations into regions like the abdominal cavity could now be undertaken. The next step was antisepsis-starting with a germ-free environment, as opposed to destroying bugs after the event. Today's operating theatres are sterile. This is portrayed vividly in the exhibit "Antisepsis and Joseph Lister", in the form of a period setting.

## Immunization

In India, immunization against infectious diseases has been practiced for at least 4,000 years. In ancient India, every village had a temple to a certain goddess named Sheetla Devi (the cool goddess) in northern India, Mariamma (the epidemic goddess) in southern India,

and several other names in other parts of the country. The temple for this goddess was usually outside the village limits, possibly to limit infection, and was open-air, exposing it to the harsh sun and rains. When small pox broke out in a village and a patient happened to be cured of the disease, he (or she) was made to bang his head on a stone called the 'bali peetham' outside the temple. After this incident, several rituals were practiced during which all people in the village were required to bang their heads lightly on the same stone to guard them against small pox. This process was called variolation, which slowly spread to the west primarily through the efforts of Lady Mary Wortley Montague of England<sup>14</sup>.

Edward Jenner was born in 1749 in Berkeley, Gloucestershire. While Jenner's interest in the protective effects of cowpox began during his apprenticeship with George Harwicke, it was 1796 before he made the first step in the long process whereby smallpox, the scourge of mankind, would be totally eradicated. For many years, he had heard the tales that dairymaids were protected from smallpox naturally after having suffered from cowpox. Records show that Jenner heard a dairymaid say, "I shall never have smallpox for I have had cowpox. I shall never have an ugly pockmarked face." It fact, it was a common belief that dairymaids were in some way protected from smallpox. Pondering this, Jenner concluded that cowpox not only protected against smallpox but also could be transmitted from one person to another as a



*Immunization by vaccination - The work of Louis Pasteur.*

deliberate mechanism of protection. In May 1796, Edward Jenner found a young dairymaid, Sarah Nelms,

who had fresh cowpox lesions on her hands and arms. On May 14, 1796, using matter from Nelms' lesions, he inoculated an 8-year-old boy, James Phipps. Subsequently, the boy developed mild fever and discomfort. Nine days after the procedure he felt cold and had lost his appetite, but on the next day he was much better. In July 1796, Jenner inoculated the boy again, this time with matter from a fresh smallpox lesion. No disease developed, and Jenner concluded that protection was complete. For this remarkable work, Jenner was elected a fellow of the Royal Society. However, many naturalists in England dismissed his work as pure nonsense<sup>15</sup>.

Louis Pasteur<sup>16</sup> knew about the work done by Edward Jenner regarding smallpox. Pasteur reasoned that if a vaccine could be found for smallpox, then a vaccine could be found for all diseases though he did not know how Jenner's vaccination worked. So he had to proceed by trial and error. In April 1881, Pasteur announced that his team had found a way to weaken anthrax germs and so could produce a vaccine against it. Pasteur and his team turned next to the disease of rabies. Most human victims of rabies died a painful death and the disease appeared to be getting more and more common in France. In 1885, a young boy, Joseph Meister, had been bitten by a rabid dog, and was brought to Pasteur. The boy almost certainly would have died an agonising death if nothing was done so Pasteur took the risk on using his untested vaccine. The boy survived and Pasteur knew that he had found a vaccine for rabies. Three months later, when he examined Meister again, Pasteur reported that the boy was in good health. Starting with smallpox, many major diseases like Polio, of the past have now been totally eradicated by a concerted programme of regimented vaccinations through the Globe, marking the end of a scourge which at one time seemed unconquerable<sup>17</sup>, but the beginnings of this achievement started with the paradigm shift in thought by Pasteur, wherein he correctly deduced that introduction of a weakened or killed strain of a pathogen will sensitise the body against any future virulent attack by the same pathogen. This principle gave birth to the new science of immunology and Pasteur's pioneering work on smallpox vaccination is portrayed in a period setting in the Gallery marking the birth of scientific immunisation by the process of vaccination.

## Antibiotics

There was a time, barely a century ago, that even a minor infection could kill you. In fact, infectious diseases were once the main killers of children and young people. Once the role of bacteria became understood, the race for antibacterial medications was on. First off the blocks were the sulfonamides, developed from dyes found to combat streptococcal infections (such as puerperal fever and pneumonia) by preventing bacteria multiplying, starting with the discovery of Prontosil by German pathologist Gerhard Domagk. However, the sulpha drugs were by no means proof against all bacterial infections.



*Antibiotics - The works of Alexander Fleming.*

In 1928, Scottish bacteriologist Alexander Fleming<sup>18</sup> noticed that a fungus mould growing on a petri dish was producing a substance that killed staphylococcal bacteria. He named it penicillin. It was not until the outbreak of World War II, when Australia's Howard Florey and Ernst Chain successfully extracted and stabilised the active principle, that its lifesaving potential was realised. However, despite subsequent mass production and the development of related antibiotics, the penicillin seemed powerless against certain infections, such as tuberculosis and typhoid. But by 1943, US researcher Selman Waksman developed streptomycin that cured these diseases and more. Other antibiotics joined the arsenal, and today they are among the most commonly prescribed drugs.

Lately, however antibiotics are in danger of being superseded by evolution of microorganisms. Our addiction to antibiotics is "breeding for resistance", knocking out weaker strains of bacteria, allowing stronger ones to flourish. Today, old killers such as pneumonia and tuberculosis have developed resistance to many antibiotics, and the focus is on finding new ones effective against "superbugs". The development of antibiotics is explained in the exhibit "Antibiotics and Alexander Fleming" in the Gallery.

## Genetics and Inheritance

People have known about inheritance for a long time. They had noticed that children resemble their parents and were already practicing domestication of animals and plants, selective breeding for good characteristics. There was however, a marked lack of understanding of the exact mechanisms involved in inheritance and genetics<sup>19</sup>.

The Greeks, as usual were first off the block and Theophrastus proposed that male flowers caused female flowers to ripen. Hippocrates speculated that "seeds" were produced by various body parts and transmitted to offspring at the time of conception. Aristotle thought that male and female semen mixed at conception. Aeschylus proposed the male as the parent, with the female as a "nurse for the young life sown within her".

There were different theories proposed to explain the similarities and dissimilarities between individuals: The blending theory of inheritance suggested that the mixture of sperm and egg resulted in progeny that were a "blend" of two parents' characteristics and the idea that individuals inherit a smooth blend of traits from their parents. This was later disproved and it was shown that traits are composed of combinations of distinct genes rather than a continuous blend. Another theory that had some support at that time was the inheritance of acquired characteristics or the belief that individuals inherit traits strengthened by their parents. This theory of Jean-Baptiste Lamarck is now known to be wrong – the experiences of individuals do not affect the genes they pass to their children<sup>20</sup>.

It was Johann Gregor Mendel<sup>21,22</sup> who in 1866 published the results of his meticulous work using pea

plants that laid the groundwork for modern genetics. This was a paradigm deviation from the existing line of thought regarding inheritance of characters. So was Darwin's monumental work, which again brought in a totally revolutionary and new line of thought that is even today opposed in many circles. A series of other related discoveries by scientists like Miescher, Morgan, Fischer and others led ultimately to the grand finale when in 1953, James Watson and Francis Crick determined the structure of the DNA molecule, which led directly to knowledge of how it replicates<sup>23,24</sup>. The understanding of genetics by humanity is a classical example of how sometimes a totally different approach is essential to arrive at new knowledge when all existing avenues of scientific investigation have been exhausted. The work of Crick and Watson continued to spawn a whole series of new discoveries aided actively by newer technologies, and today we have a huge corpus of knowledge which help us understand what did not, a mere five decades ago<sup>25</sup>. It is a classic example of a "Scientific Revolution". The steps leading to this revolution has been depicted in many exhibits in the Gallery, each time emphasizing the departure from the beaten path to arrive at new knowledge.

I will briefly mention some other paradigm shifts in the field of biomedical revolution that are depicted in the galleries.

## Pharmacology

Existing thought: Mankind had, very early in the course of civilization, discovered that certain substances of plant, animal or mineral origin had ameliorative properties in curing certain ailments. Early pharmacology consisted of isolating the active components of these substances and searching for newer and more effective substances, more often than not, depending on serendipity for discovery of new drugs<sup>26</sup>.

Synthesis of drugs with desired/designed properties started with Wohler who synthesized organic compounds from inorganic substances and the subsequent work done by Rudolf Buchheim and Oswald Schmiedeberg. Newer drugs began to be created, reducing dependence on naturally occurring substances. However even now the "one size fits all" technique is followed by most drug designers.

This sometimes resulted in adverse drug reaction among some patients to a prescribed drug. Ingesting and injecting drugs and chemicals indiscriminately into the bloodstream hoping that they will be delivered to the diseased or infected tissue is something shooting at a crowd blindfolded. It may cause more harm than good.

The next paradigm shift is expected from the results of works being done in two different directions<sup>27</sup>. Anything that happens in the body, be it growth, disease, everything is dictated by genes. Even diseases that are clearly caused by external agents are influenced by genes. And then there are diseases that can be directly attributed to genetic defects. Such diseases can be prevented by appropriately tinkering with the genetic makeup of the individual. Such techniques are now available. Secondly advanced drug delivery systems like carbon nanotubes, nanorobots, buckyballs etc., are being explored as vehicles to focused delivery of drugs reducing side effects significantly<sup>28</sup>. All these concepts are depicted in the Gallery.

### Psychology and Psychiatry

Early human beings thought that mental illnesses were of mysterious origin or the work of the devil. Treatments were equally weird and consisted at best of techniques like faith healing and praying, and worst, chaining and incarceration of patients with psychoses for life<sup>29</sup>. The works of Freud<sup>30</sup>, Adler<sup>31</sup>, Jung<sup>32</sup>, Penfield<sup>33</sup> and others led to the advent of psychology and psychoanalysis, which represents the first paradigm shift in the amelioration of several mental illnesses.

The way such patients were treated earlier betrayed a lack of knowledge of the real source of such illnesses. Restraining mentally ill patients to asylums and administering what were known as shock therapies (administering several kinds of shocks including malarial therapy for general paresis, insulin shock therapy, cardiazol shock therapy, and electroconvulsive therapy), were the general methods used. The apparent success of the shock therapies, despite the considerable risk they posed to patients, also led to more drastic forms of medical intervention, including lobotomy.

Despite the work of pioneers mentioned above, there existed two very important lines shortcomings till the

beginning of the twentieth century, which dominated the treatment of mentally ill. An inability to pinpoint the organ and the exact region therein, where mental illnesses originated and the brute force methods employed to contain and apparently cure such illnesses. The identification and mapping of the brain as the source and hence the organ which should be dealt with either medically or through surgery, came about in the beginning of the twentieth century. The works of António Egas Moniz<sup>34</sup>, who shared the Nobel Prize for Physiology or Medicine of 1949 started using lobotomy or leucotomy, which involved what came to be known as psychosurgery, a procedure where parts of the pre frontal cortex of the brain were removed or connections severed, to ameliorate mental illnesses. Though such procedures had several detractors, the study of behaviour of deliberately or accidentally lobotomised or partially lobotomised patients by researchers like Vilayanur S. Ramachandran<sup>35,36</sup> have since led to heretofore unknown insights into the working of the human brain. Simple therapies for problems like the “Phantom limb” have been devised.

The work of Franco Basaglia<sup>37</sup> in Italy, on the methods employed to treat institutionalised patients was also another paradigm shift in the way society looked at such illnesses. Observing that many of the symptoms of mental illnesses amplified because of institutionalisation, and that such symptoms vanished when they were freed of the forcible restraint practised in institutions, Basaglia concluded that many so called abnormal behavioural traits would dissolve when the patients were freed from the asylums. He advocated that allowing the mentally ill to integrate into the society and live as normal a life as is possible can be a better option. Pharmacology and newer imaging techniques also actively aided in development of newer treatments. Though not very much in practice the free association psychoanalysis pioneered by Freud represented a radical shift from earlier crude techniques to methods that concentrated on human thought processes. So did the works of other pioneers mentioned above. This is depicted by graphic panels and a period setting of Freud practising psychoanalysis in the Gallery.

### Medical Imaging

Humankind has always been handicapped by its inability to look into a live body and find the source of the ailment and this had made medicine a science that

often worked by trial and error. The first noteworthy step in body imaging took place in the turn of the 20th century by Wilhelm Konrad Roentgen<sup>38</sup>, who discovered x-rays in 1895, a discovery for which he received the first Nobel Prize for Physics in 1901. Imaging science has evolved in three stages. In the first stage, the aim was to develop imaging techniques to define the anatomic features and functions of the internal organs. Other methods for this purpose were also used, including ultrasound and radioactive tracers, and contrast agents were developed to reveal previously indiscernible structures. In the second stage, the interior of the heart and blood vessels were delineated by angiography and other new tools including Computerised Tomography (CT/ CAT scan)



*Psychology and Psychiatry - A period setting showing the work of Sigmund Freud.*

and Magnetic Resonance Imaging (MRI), which permitted resolution of very small structures throughout the body. As a third stage, imaging methods are now being used to guide therapy directly – from long-term guidance of cancer therapy to immediate, on-line guidance of minimally invasive surgery as in case of laparoscopic and robot assisted surgeries. It can clearly be seen that engineering, chemistry and physics played a major role in development of such non invasive imaging methods that helped the therapist clearly see the interiors of the human body without taking recourse to invasive techniques.

## The Gallery

The Gallery is laid out in a six thousand square feet area

with forty four interactive exhibits, period settings and graphic panels, not arranged in chronological sequence, but as a series of clusters depicting paradigm shifts in scientific thought that led to the development of biomedical science as bursts of knowledge rather than as an unbroken continuum.

It begins with a quote in the Indian classical language Sanskrit on medicine and is followed by a visual seeker – a large curved graphic panel in the background with a touch screen monitor on a rotary platform in front. The graphic covers the whole history of medicine from prehistoric times to the present in the form of a collage. The touch screen monitor when pointed towards one section of the graphic, displays a multi layered animated/graphic/video information database giving further details about that period of civilisation. The touch screen enables the visitor to get in depth information about key paradigm shifts in the history of medicine. This is followed by a series of exhibits depicting the contrast between past and present practices in medicine and dioramas about the Indian tradition in medicine. An exhibit showing another paradigm shift – the advent of hospitals – which saw patients going to a central location equipped with expertise and infrastructure to be cured, rather than the wait for the wandering medicine man to visit and treat his ailment. The next exhibit depicts a period setting of surgical traditions in ancient India – talking about rhinoplasty, which arose as a result of societal needs as described earlier.

The second part starts with a discussion about the 'Age of Biology' followed by a series of exhibits which show how there were several things that were not understandable using the existing corpus of knowledge in biology at that time, like how blood circulates, how the sex of a child is determined, what caused infectious diseases, lifestyle diseases, why some diseases were curable, while some were not, psychopathology etc.

This is followed by an exhibit which talks about 'Challenges that spurred the Revolutions', which summarises the conundrums of those periods in history, when medicine came to a standstill. Thereafter, come another series of exhibits, which talk about the paradigm shifts that created understanding of each of these dead ends, like Microscopy, Immunology, understanding of the germ theory of diseases, sepsis

and antisepsis, antibiotics, psychology and psychiatry etc. Each of these are set in an eye catching period setting, capturing a particularly poignant scene that marked a turning point in the understanding of heretofore unknown concepts, featuring the pioneers in the these respective fields. Thus there are period settings showing pioneers like Sushruta, Jenner, Lister, Freud and Fleming at work.

Each of these works are elaborated in further detail in a series of exhibit clusters. There is a visual seeker talking about the history of immunisation, the specifics of immunology, psychoanalysis, the works of neuropsychiatry pioneers, antibiotics and their mode of working antisepsis and how it works etc.

Traditional pharmacology is discussed in one exhibit and then the newer technologies like tailor-made drugs, advanced drug delivery systems, nanotechnological methods of drug delivery, genetic medicine etc. are discussed to show several paradigm shifts in the field of pharmacology.

There was a time in the history of medical technology, when loss of an organ meant living without it for life, or simply dying. The concept of transplantation and implants and indeed augmenting existing human prowess by implanting devices that perform better or over a wider spectrum than natural organs is discussed in detail. This future trend might create an "Augmented Human Being" as described in an exhibit by the same name. The shift in thought brought about by the conception of transplants and implants is talked about in a series of five exhibits.

Understanding of heredity, genetics and the genome marked another landmark. This is elaborately discussed in a cluster of nine exhibits, starting with the description of the works of Mendel, Crick and Watson and ending with a period setting of the Human Genome Project. In between, the techniques of genetic engineering, like Polymerase Chain Reaction, Gel Electrophoresis and DNA Microarray, all technologies that aided the Human Genome Project have been elaborated using interactive exhibits. The possibilities that open up for therapy on account of the mapping of the human genome is established in this section.

Though the advent of microscopy and the use of dissection for seeing inside the human body brought



*Advances in Medical Imaging showing non invasive imaging methods.*

about a paradigm shift in the understanding of anatomy and physiology of the human organism, they were not of much help in looking into a live human body to detect diseases and disorders. Non invasive imaging techniques, starting with the discovery of X-Rays and their use in body imaging, overcame this handicap. Extremely detailed imaging of a live human body using non invasive techniques were developed one after the other and this is depicted in a series of highly interactive exhibits like 'Magnetic Resonance Imaging', 'Endoscopy', 'CT Scanning' etc.

The present and future of biomedical technology, as we see it today, is discussed in another series of seven exhibits, where stem cell therapy, telemedicine, robotic surgery, laparoscopic surgery, cloning for organ harvesting etc. in an interactive format.

The Gallery ends with a highly interactive format exhibit "Ask the Expert", where the visitor can, using a touch screen interface, select from a list of several questions from the frontiers of biomedical technology and select any one from a panel of experts to answer the question in a pre recorded video format. There is an automated quiz, where random questions related to the topics covered in the Gallery, with special emphasis on the paradigm shifts can be answered by three teams of participants. The Final exhibit talks of the far future, and what we can expect in these different fields that were talked about in the exhibits in the coming decades.



*A highly interactive format exhibit "Ask the Expert".*

The Gallery is richly supplemented by supporting information in the form of graphics showing the pioneers who brought about change, the changes that they brought about, and the ways in which these changes affected the overall health scenario of the society, the aim again being to emphasise that biomedical technology advanced not linearly, but as a series of singularities that constituted a Biomedical Revolution.

## Learning Experiences from the Gallery

Three categories of view changes that visitors experience, when they visit places like Science Centres have been identified. These are changes in -

- *Opinions* : People's immediate thoughts and feelings about a topic those are relatively easy to manipulate
- *Attitudes* : More strongly held beliefs about the world and how it works
- *Values* : underlying and strongly held beliefs (e.g. belief in God, animal rights, the death penalty) which are formed early in life, are very difficult to change and tend to harden as the person grows older<sup>39</sup>.

Given that most researchers believe that visitors are likely to have chosen to visit the Science Centre / Gallery on the basis of their matching attitudes and values, one would assume that a gallery can perhaps best try to change opinions, that too minimally, on the topic it attempts to portray<sup>40</sup>.

Though this gallery was a part of a Centre that was built by the National Council of Science Museums to be handed over to another agency for operation, and not

much time was available for a detailed study, the author did spend a few days taking around select groups of students of the age group 14 -18 through the Gallery. Though the sample was small, the understanding that emerged from interaction with these visitors is that there was a significant shift in opinion. Most students, were not aware that advances in Biomedical sciences occurred not just as a continuum of accumulation of related knowledge, but significantly as a result of a series of paradigm shifts in understanding. But post visit, the opinions expressed by the visitors, as evinced in comments like "In that case I can do something that will cure AIDS too" (a 14 year old girl) or "That means even non biology students can contribute to the growth of biomedical sciences" (a 17 year old boy) show that the idea of paradigm shifts contributing to revolutionary changes was well received. Some students even attempted to hypothesize wildly by tossing about ideas like infusing chloroplast into the skin cells of human beings so as to allow them to synthesize glucose from sunlight and not depend on plants for food. In fact I would go to the extent of saying that even attitudes and values were seen to be changing in a small way when opinions like a positive attitude towards Euthanasia, organ transplants, stem cell research etc. were expressed, and especially when one visitor who said that medicine is perhaps a noble profession (which he had some doubts about, owing to certain personal negative experiences). I add the caveat that the samples studied were small and the average age of the students studied was impressionable. Nevertheless, it is felt that the Gallery indeed did serve the purpose of creating opinion and to a very small extent to modify attitudes and values.

## Conclusion

A science advances not linearly, as a cumulative addition of new knowledge gathered as a refinement of the existing corpus of knowledge, but in distinctly discrete spurts, aided by thought lines arising from totally unrelated fields, which are often radically different from existing lines of thought. While this is true of all sciences, it is especially true of medicine and that is what is sought to be established in this Gallery on the Biomedical Revolution. A Gallery portraying this concept can change not just the views of the visitor regarding perception of the history of science but also influence attitudes and values to a limited extent.

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# Deciphering Human Microbiome

**Subha Sankar Ghosh**

## Abstract

*This article reviews the Human Microbiome Project which was launched to decipher the identity and interactions of the microbes that inhabit our body. A generalized idea has been given about human microbiome and the novel techniques used to identify these microbes and their interactions with us. The results that were obtained have also been discussed, which may open up a new vista in the field of research and medicine.*

## 1. Introduction

Antonie Philips van Leeuwenhoek (1632-1723) is considered the first microbiologist who observed single celled organisms through his handcrafted microscope. He called them 'animalcules'. Subsequent works by scientists helped us to understand these tiny organisms and their role in nature. Microbes play a vital role in our daily lives. While on one hand they are responsible for many dreaded diseases like dengue, tuberculosis, malaria, AIDS etc., on the other hand they are constantly working to keep us healthy.

A healthy human body is home to trillions of microbes. The association of microbes with humans is known as human microbiome. This concept was first suggested by Joshua Lederberg, who coined the term

'microbiome', to signify the ecological community of commensals - the symbiotic and pathogenic microorganisms that literally share our body space<sup>1</sup>. Surprisingly 'majority' of these microbes are not associated with any known harmful effect but their presence is found to be vital for maintaining the normal health of humans<sup>2,6</sup>. As such, a search has been initiated to solve this great enigma.

In 2007, a revolutionary project called Human Microbiome Project (HMP) was launched<sup>11</sup>. The aim of the project was to decipher and characterize human microbiome and its probable association with the incidence of disease. It was an interdisciplinary effort which was launched worldwide involving 200 scientists and 80 institutions from USA, Europe and Asia<sup>2,7</sup>.

Before we explore the intricacies of the project, it will be pertinent to discuss about microbes in general.

## 2. Microbes

Microbes are a group of tiny organisms (around 200000 nanometre in size) that cannot be seen with naked eyes. Their fossils date back to more than 3.4 billion years, when life was beginning to originate on Earth. They are found almost everywhere on Earth - air, soil, rock, water, ice, hot streams, plants, animals and even on humans. They play a vital role in maintaining the ecological balance of Earth.

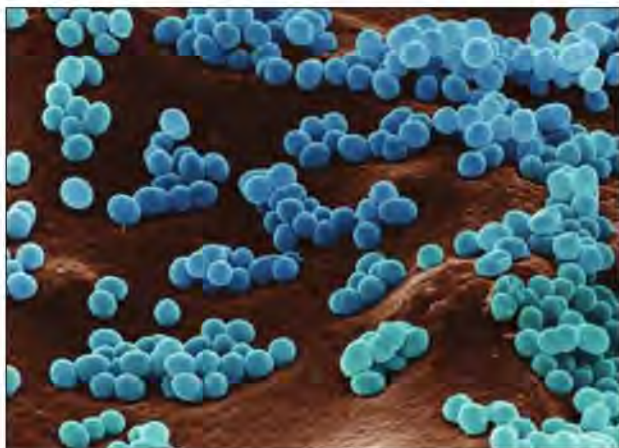
Microbes represent a diverse group of organisms which are broadly categorized as follows-

**a. Prokaryotes** - These organisms do not have membrane bound nucleus i.e. the genetic material, DNA, is not enclosed inside the nucleus. Their DNA is single, circular with around 3 to 6 million base pairs. On an average, around 500-10,000 genes are found in their DNA. They are the most diverse and abundant group of organisms known on Earth.

Within this group are found the Archae (Archaeobacteria) and the Bacteria.

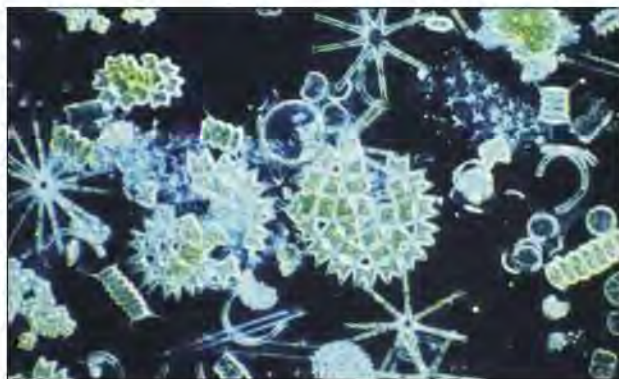


*Antonie Philips van Leeuwenhoek.*



Archaeobacteria are primarily extremophiles, meaning these are found in extreme conditions like high temperatures (more than 1000 °C), high alkalinity or acidity and extreme salinity while bacteria are found almost everywhere.

**b. Eukaryotes** - These organisms have well defined nucleus as well as membrane bound organelles. This group contains both unicellular and multicellular organisms. Most of the members of this group can be seen with naked eye in their adult form. Human beings belong to this group.



Interestingly there are some eukaryotes that can be seen only with the help of microscopes and hence called microbes. It includes diverse unicellular microscopic eukaryotic organisms, the protists and groups of very small animals like arthropods, crustaceans, nematodes, rotifers and unicellular fungus.

**c. Virus** – They are a group of organisms who are ‘at the edge of life’. They are non-living outside the body

of the host but start replicating the moment it invades a host. They are submicroscopic, with size ranging from 5 to 300 nanometers with some exceptions. Their genetic material is either DNA or RNA. The uniqueness of this group has prompted many scientists not to consider them as a living organism, which makes their inclusion within the microbes debatable.

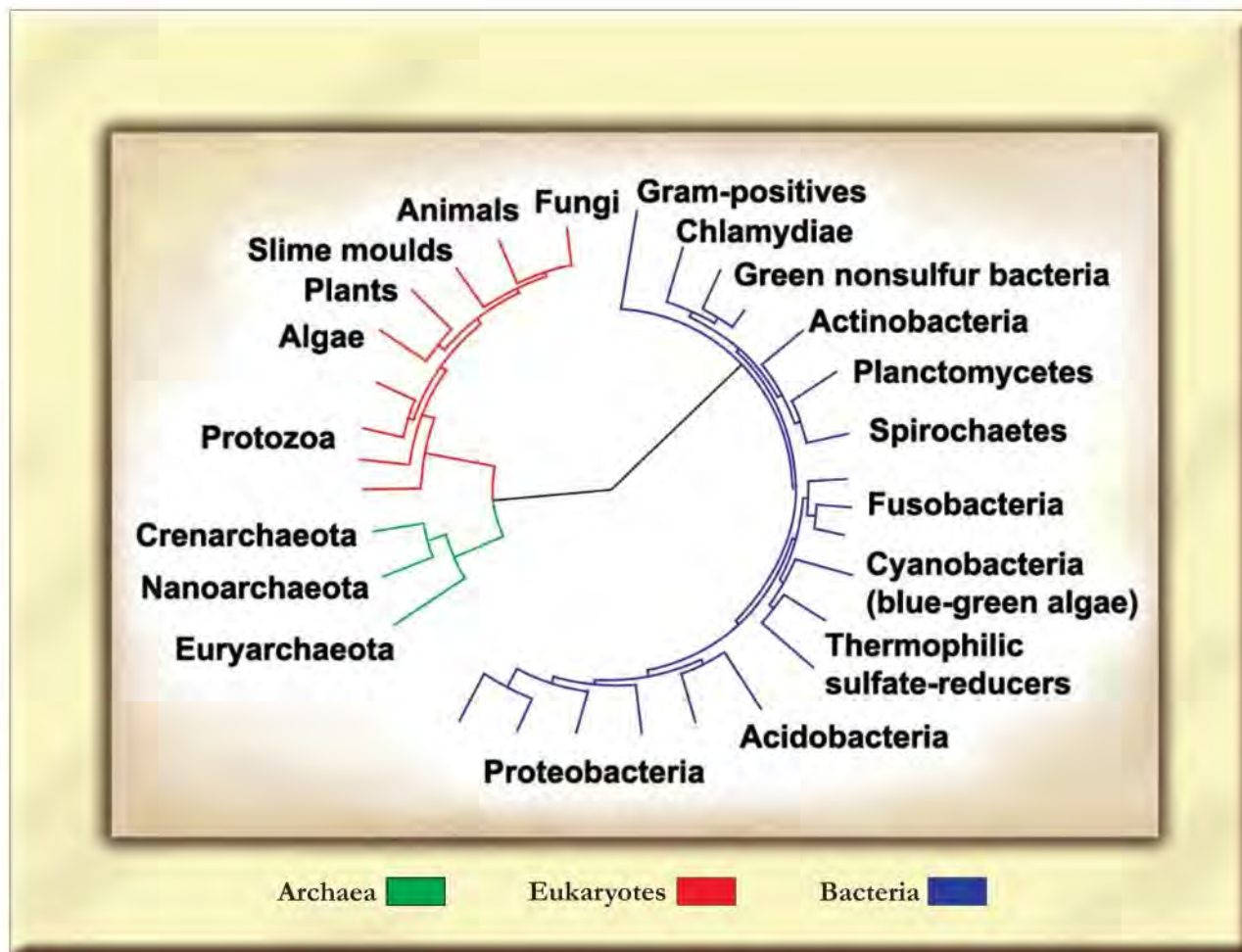
When the biodiversity of all the recorded organisms found on Earth is taken into account, it is found that microbial diversity far outnumbers the relative diversity of any other group of organisms.

### 3. Human Microbiome

Human microbiome is an association of estimated  $10^{14}$  micro organisms that live inside and on humans. It is the entire aggregation of microbes, their genomes and their interactions with us<sup>10</sup>. As per Human Genome Project, the approximate number of genes present in human genome is around 20000, but the number goes up to more than 100000 if the total genetic diversity of the microbes that constitute the human microbiome is taken into account<sup>7</sup>. These microbes live primarily as commensals forming a special kind of symbiotic relationship where one species is benefitted whereas the other may remain unaffected.

Recent studies have shown that the biggest reservoir of microbes is our gut that harbour around 7000 strains of microbes. These microbes influence our nutrition uptake which in turn controls our overall health and metabolism<sup>10</sup>. Microbes help to synthesize Vitamin K and Biotin within the gut. In addition, they have a positive influence on our immune system. But very little is known about the identity of the microbes constituting the microbiome and the factors that may be responsible for creating an imbalance in the microbial community at different body sites<sup>9</sup>.

Even though all humans have 99.5% similarity at the genetic level it is not certain whether all humans, irrespective of race, colour or ethnicity have an almost identical ‘core’ microbiome. If there is a core microbiome, one wonders how this constancy has been maintained and transmitted through generations. We do not know whether difference in microbiome among individuals have an important role in predisposition to



*Phylogenetic tree showing the diversity of bacteria compared to other organisms.*

different diseases. It will be interesting to know whether transplanting microbiome from a healthy individual to a diseased one can cure a disease. Does our microbiome characteristic change with the changes in our lifestyle? It is also not known whether antibiotics play a decisive role in influencing the basic composition and stability of the core microbiome. These are some of the important questions that need to be answered.

#### 4. Human Microbiome Project (HMP)

Human Microbiome Project was launched in 2007<sup>11</sup> with the ultimate objective to determine whether the health of humans can be improved by tinkering with the microbiome. It was a five year project with a total budget of over \$150 million.

The goals of the HMP<sup>1</sup> are:

- (1) To study the human microbiome in detail by collecting samples from multiple body sites from 'normal' volunteers and analyzing the same using newly developed high-throughput technologies
  - (2) To determine any correlation between incidence of disease and variation in the microbiome among individuals taking cue from different medical conditions
  - (3) To generate a standardized data resource and new technological approaches that would help the scientific community to undertake such studies on a broader scale
- Due care has been taken to consider the ethical, legal and social implications of such studies.

One of the major aims of HMP was to decipher the

sequences of around 900 bacterial genomes that could be used as a reference.

This was accomplished by collecting samples from five different body sites of the volunteers, identifying the microbes using 16S rRNA gene sequencing and comparing it with the available database of the known species. This was followed by metagenomic shotgun sequencing on the same samples to identify the genes present in the population and their probable functions. The results so obtained have helped ascertain whether core microbiome exists at different body sites<sup>1</sup>.

Genome sequencing work for the above project is being done at the following HMP-funded large-scale sequencing centers: the Baylor College of Medicine Human Genome Sequencing Center, Houston; The Genome Institute at Washington University School of Medicine, St. Louis; The J. Craig Venter Institute, Rockville, Md.; and the Broad Sequencing Platform, Broad Institute of Massachusetts Institute of Technology and Harvard<sup>3</sup>.

#### 4.1 The First Step

To start with, 242 healthy volunteers (129 male, 113 female), aged between 18-40 years were chosen. The volunteers were so selected that they represent a reasonably diverse group of race, ethnicity and other factors. Samples were collected from 18 body sites in women and 15 body sites from men, upto three times<sup>2,3</sup>. The habitats were distributed among five major body areas - nasal, oral, skin, gastro-intestinal tract and urogenital tract. The specific sites within these broad areas are as follows.

- From the oral cavity and oropharynx: saliva, buccal mucosa (cheek), keratinized gingiva (gums), palate, tonsils, throat and tongue soft tissues, and supra- and subgingival dental plaque (tooth biofilm above and below the gum), nine specimens were collected.
- Four skin specimens were collected from the two retro auricular creases (behind each ear) and the two antecubital fossae (inner elbows).
- One specimen from the anterior nares (nostrils).
- To study the microbiota of the lower gastrointestinal tract volunteers collected stool specimen of their own.
- In case of females, three vaginal specimens were collected from the vaginal introitus, midpoint and posterior fornix<sup>3</sup>.



Source : NIH Medical Arts and Printing

Approximately 5000 samples were collected from the volunteers. The microbial genome was purified and isolated from the human genome with the help of 16S rRNA sequences which is unique to bacteria. In addition 3.5 Terabase (an amount of genetic sequence data equivalent to  $10^{12}$  base pairs) of nucleotide sequence was also obtained from microbes, which have been used for metagenomic sequencing<sup>3</sup>.

#### 4.2 Unearthing Microbial Diversity in Microbiome

Studies have shown that microbes live in communities. They interact and communicate among themselves in complex manners by exchanging nutrients, biochemical products and chemical signals without direct cell to cell contact, utilizing the medium in which it is growing. These associations have evolved over the ages. The microbial diversity at a site influences the presence of other microbes at that site<sup>3</sup>. As such, deciphering the identity of all the microbes present at a site may help us understand the microbial interactions and explain the presence of certain microorganism at that site.

It has been found that a majority of microbes found on different sites of our body are uncultivable under laboratory conditions<sup>1</sup>. These posed a real challenge as traditional microbiology is based on studying a microbe by isolating a single bacterium from the site and growing it in a culture medium like nutrient agar in the laboratory. Thereafter the cultured bacterial genome is sequenced and the identity of the same is established.

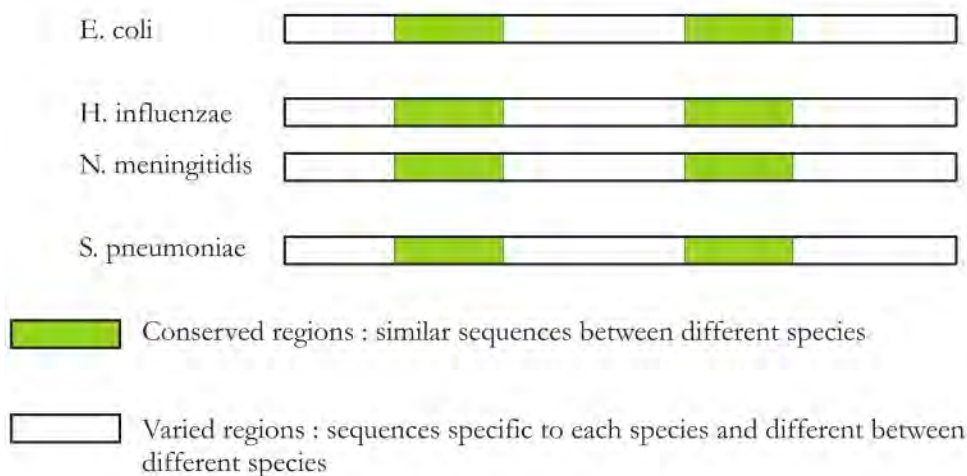
To overcome this challenge, novel methods have been devised that helped identify such microbes and sequence their DNA, bypassing the need to grow it in the laboratory.

The major tools that were employed to study the microbial diversity were 16S rRNA sequencing and Metagenomics<sup>1</sup>.

## a. 16S rRNA Gene Sequencing

The 16S rRNA gene is 1542 nucleotide long and is highly conserved. It acts as a signature molecule for the bacterial identification. Apart from helping to differentiate the bacterial genome from the human genome, it also helps in differentiating one group of bacteria from another from the evolutionary point of view.

The nucleotide sequence of the 16S rRNA gene consists of highly conserved regions which is common among all the bacteria. In addition there are nine variable regions or nucleotide sequence (V1-V9). The variable regions help to identify and categorize the bacteria into different taxons<sup>6</sup>.

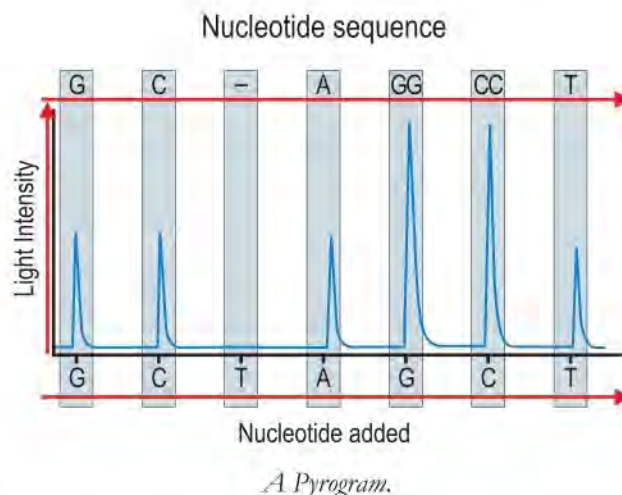
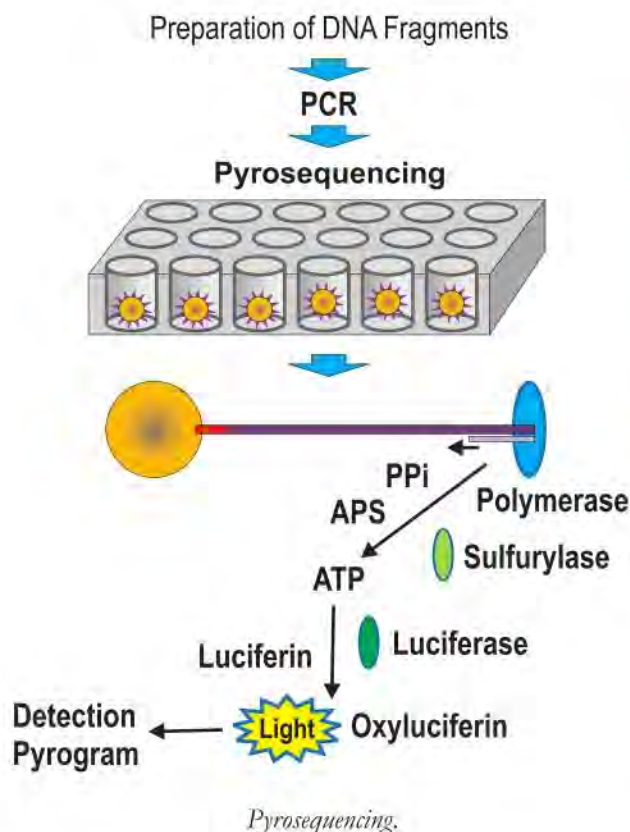


*Comparison of 16S rRNA gene of different Bacteria.*



**CONSERVED REGIONS:** unspecific applications

**VARIABLE REGIONS:** group or species-specific applications



Source : [www.journalofmicrobiology.net/index.php/jom/article/viewFile/10743/19325/50704](http://www.journalofmicrobiology.net/index.php/jom/article/viewFile/10743/19325/50704)

To study the 16S rRNA gene, the bacterial DNA corresponding to 16S gene is isolated and separated into single strands. Thereafter it is amplified by PCR and then sequenced using the principle of pyrosequencing. Pyrosequencing is a Next Generation Sequencing technology (NGS) where the sequence of an unknown DNA strand is determined by synthesizing a complementary DNA strands enzymatically, one base at a time. Incorporation of bases one after another, on to the single stranded complementary DNA results in the generation of visible light that is captured by a camera. The intensity of light so emitted is plotted in a pyrogram and the sequence is determined.

In HMP, the 16S rRNA gene region consisting of number three (V3) to five (V5) variable regions (V35) was chosen for analyzing 4,879 samples. Samples were amplified and sequenced using Roche-454 FLX Titanium platform. Sequence of V1 to V3 (V13) window was also included for a subset of 2,971 samples to provide a complementary view of taxonomic profiles.

Approximately 5,000 samples for 16S rRNA gene sequencing by 454 FLX were collected, sequenced and tracked in combination with clinical and sample metadata, and the resulting data were finally deposited in public database. For analyzing the microbial data, specialized software tools like 'Mothur' and 'QIIME' have been used. Sample studied from the above technique has given a comprehensive view about the specific assemblage of microbiome community structure at different body sites. In addition, comparison of these sequences with the already available public database also helped in identifying new bacterial species at those sites.

Thereafter samples from different body sites are exposed to Metagenomic Shotgun sequencing for detailed analysis. This process helped to identify the genes of the microbes and their associated functions.

## b. Metagenomic Shotgun Sequencing

Metagenomics is an amalgamation of genomics, bioinformatics and system biology. It involves the study of the genomes of many organisms simultaneously which helps in understanding the complicated microbial interactions. This approach offers a more global view of the community, allowing us to better assess levels of phylogenetic diversity and intraspecies polymorphism, study the full gene complement and metabolic pathways in the community, and in some cases, reconstruct near-complete genome sequences.

Whole Genome Sequencing also has the potential to discover new genes<sup>4</sup>.

In HMP, 'Illumina shotgun metagenomic reads' technology has been used to sequence and catalogue the microbial DNA directly from the samples collected from different body sites, without culturing them in the laboratory. It has helped in the construction and assembling of reference genomes. The taxonomic profiling of the data so obtained was done using computational tools like 'MetaPhlAn' whereas 'HUMAN' was used to study the metabolism of the microbes. 'PATRIC' database was used to identify the potential pathogens<sup>3</sup>.

In order to carry out metagenomic analysis of the microbes, the samples that are collected from different body sites of the volunteers are quality filtered to isolate the microbes from human cells. Sample contamination of human cells ranged from less than 1% in stool to around 99% in vaginal and nasal samples. Moreover a single human cell contains roughly 6 billion base-pairs (bp) of DNA as compared to just 4-6 million bp found in a typical bacterial cell. As a result the

removal of contaminant proved to be a herculean task. Removal of contaminant has reduced the original sample size of 8.8 Tera bp to 3.5 Tera bp<sup>11</sup>.

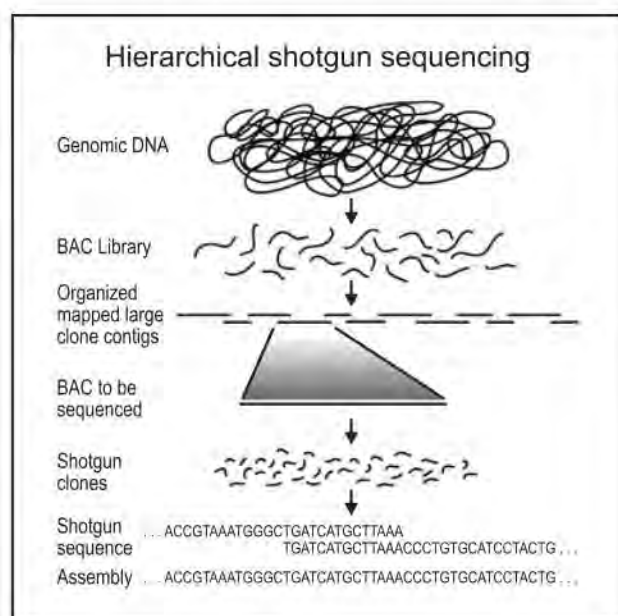
Samples with 50-100 ng of microbial DNA were used for analysis. The DNA so isolated is broken up randomly into numerous small segments of approximately 194 nucleotides. These segments are then sequenced directly to determine the order of nucleotides. Specialized sequence assembly software in addition to inexpensive, high-throughput DNA sequencers are used to reconstruct these numerous fragments of the entire community of microbes into the original sequence.

In addition to the above technique, the segments have also been cloned and incorporated in laboratory bacteria to form a library that can be used later to analyze the DNA sequence or to study the metabolic activity of the gene segments by decoding the proteins so produced by them.

## 5. Findings of HMP

HMP has helped researchers to get an overall picture of a normal human microbiome. Till date the HMP has released over 100 million 16S rRNA gene reads<sup>11</sup>. Researchers have found that there are more than 10,000 microbes found on a healthy human body of which the identity of 81-99% of the microbes has been deciphered. These microbes contribute nearly 8 million protein genes in the microbiome<sup>2,5</sup>. Interestingly the microbial diversity is greatest in the gut followed by mouth, throat and gums while it is least on the skin and in the vagina. In addition evidence of 'core' microbiome have been found for different sites like mouth, gut, nose, skin and vagina<sup>8</sup>. Use of advanced computational tools has helped to catalogue around 100 opportunistic pathogens found in the microbiome<sup>5</sup>. Studies prove that the microbial community composition is different in different people. But this diversity changes with the state of health or in response to the application of antibiotics which return to a state of equilibrium during the course of time. Again, irrespective of the microbial diversity at different sites in different individuals, the core metabolic functions at those sites remain the same<sup>2,3,5</sup>.

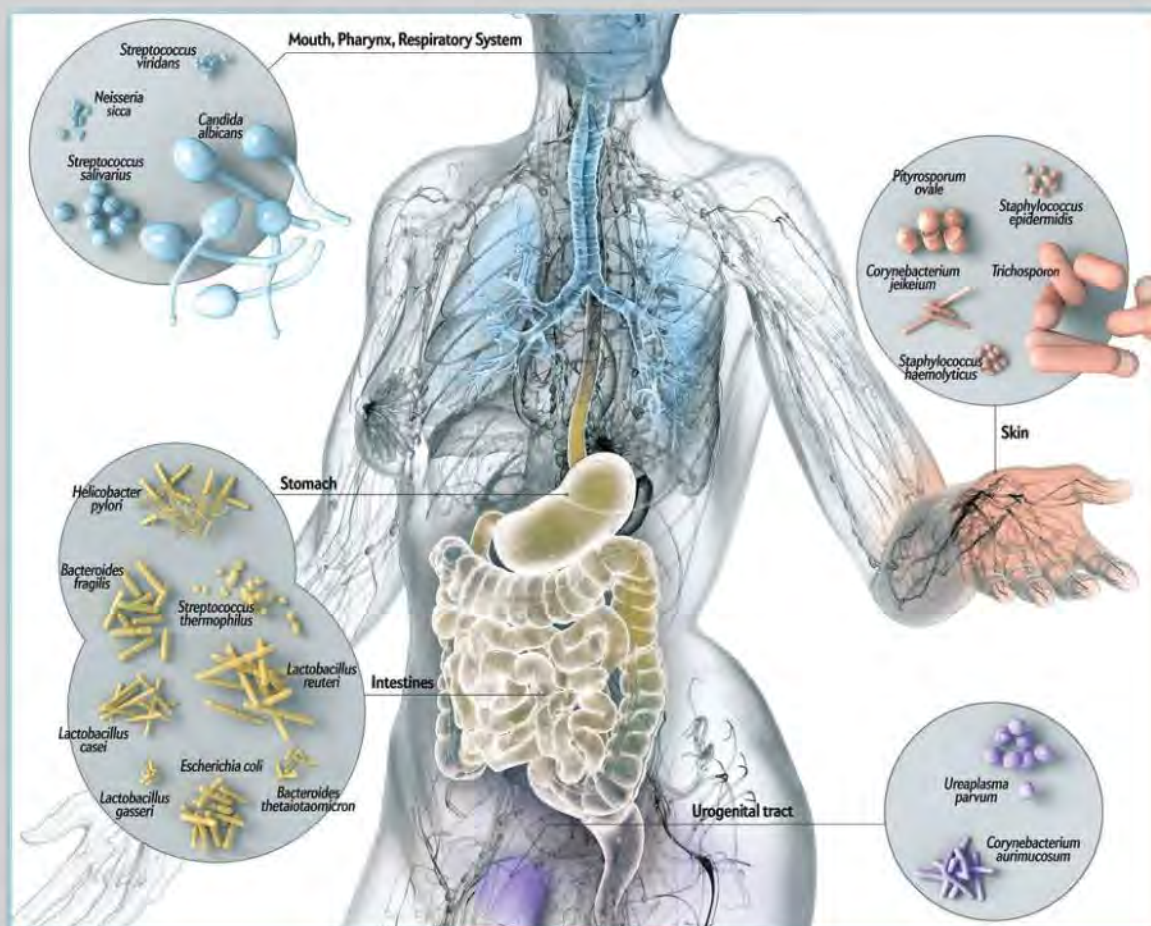
One of the major goals of launching the HMP was to



*A model of Metagenomic Shotgun sequencing.*

*Source : Nature Publishing Group, IHGSC, Initial sequencing and analysis of the human genome, Nature, 409, 860-921*

## 5.1 Clinical Applications of HMP



Source : Sc. Am. June 2012

### Human Microbiome.

find association between the microbiome and predisposition to disease. Based on the findings so far, some interesting facts emerged which has clinical applications :-

a) Vaginal microbiome composition changes with the onset of pregnancy turning itself into a healthy passage which helps to introduce the baby to the first dose of microbes during childbirth. This finding proved that babies born through caesarean section are exposed to different sets of microbes than babies born of normal delivery. This may have implications in the development of their immunity in future<sup>2</sup>.

b) The nasal microbiome of the children below 3 years of age who were suffering from unexplained fever was examined. It was found that they contain fivefold more viral DNA than normal children. So application of antibiotics to treat them may not be a good option<sup>2</sup>.

c) Microbial imbalance plays a major role in the development of inflammatory bowel disease like Crohn's disease. Again the genetic makeup of individuals have a positive influence on the composition of the microbes inhabiting the gut. Studies show that Paneth cells present in small intestine may play a vital role in restoring the gut microbiota equilibrium<sup>12</sup>.

According to Francis S. Collins, Director of National Institutes of Health, 'HMP created a remarkable reference database by using genome sequencing techniques to detect microbes in healthy volunteers. This lays the foundation for accelerating infectious disease research previously impossible without this community resource'.

Encouraged by the results, researchers are planning to decipher the complex microbes including archae, eukaryotes and viruses that form an integral part of microbiome<sup>1</sup>. This will be done by conducting studies on more number of volunteers from different ethnic groups worldwide. These studies would give a comprehensive view of the microbiome which can be utilized for making our lives better.

## Acknowledgement

I am thankful to Mrs. Amita Ghosh and Mrs. Anuradha Nair, Research Fellow, Bhabha Atomic Research Centre, for their valuable inputs.

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*Published by: National Council of Science Museums, Kolkata, India*

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